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A REPORT ON

ENHANCEMENTS FOR EXISTING AND FUTURE HELICOPTERS SUPPORTING OPERATIONS OF THE CANADIAN OIL AND GAS INDUSTRY

PREPARED FOR

THE CANADIAN PETROLEUM ASSOCIATION

PREPARED BY

SURVIVAL SYSTEMS LIMITED

JUNE 15, 1989

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EXECUTIVE SUMMARY

In today's world of ever changing technology and rapid development in a field such as aviation, it has become important to understand the latest changes and improvements that directly affect the safety of passengers and crew, and the efficient operation of helicopters.

The Canadian Petroleum Association (Frontier Division) has recognized the need to investigate and determine those enhancements that pertain to the safe operation of helicopters in support of oil exploration and production.

Consequently, the Canadian Petroleum Association commissioned this study.

Section I gives an overview of the study. Section II provides a background of the problems related to helicopter accidents. This section looks at the human tolerance limits in helicopter accident situations and some of the environmental hazards.

Section III is the heart of the report. This section deals with seven safety enhancement topics. These topics include structures, seats, restraint harness, fuel and fuel systems, overwater operational systems, wire warning devices and flight data recorders. Under each topic, information is provided on related accidents; developments and research; industry, academic and regulatory recommendations; conclusions; and equipment availability.

Section IV, Conclusions, attempts to identify practical areas for safety enhancement. Here it is suggested that shoulder restraint harnesses and crashworthy fuel systems are practical safety enhancements with minimal weight and cost penalties. For overwater operations, externally mounted automatic deployed liferaft systems, retrofitting helicopter floatation bags with scoops and new developments in aviation liferafts should be considered for enhancing overwater flight safety. Energy absorbing devices are possible enhancements for new helicopter acquisitions and wire warning devices should be considered in certain operations. As well, flight data recorders can be considered to enhance flight safety and accident prevention programs and are likely to become required in helicopters in the future.

The report also contains a Bibliography and an annex. The annex contains promotional information on safety enhancement systems collected from manufacturers and suppliers.

1.0 INTRODUCTION

The Canadian Petroleum Association, Frontier Division, contracted Survival Systems Limited to conduct a study to determine those safety enhancements which pertain to the safe operation of helicopters in support of oil exploration and production. The information in this report was derived from current research, aviation occurrence reports and information from industries and agencies involved with helicopter safety.

2.0 BACKGROUND

"Passengers can be and are safely carried by airplanes, and as many as seven passengers have been carried at one time. As a rule these trips were made merely for the novelty of the experience, but on several occasions doctors found airplanes of the greatest value when compelled to travel a long distance at utmost speed. As airplanes rapidly travel from sixty to seventy-five miles an hour, and can travel a straight line from place to place, they can transport a passenger or mail with the utmost dispatch when required.

In wartime airplanes also played quite an important part, and whereas their true value in warfare was questioned until really tested, they have now proved to be of great use in actual hostilities. To be sure, an airplane is now and again struck with a shell and brought to earth. But even if the operator is killed, the loss of a single machine and operator in this way is of no great importance as compared with the service rendered. Moreover, the falling airplane, or even the falling aviator, may kill or disable a number of the enemy, and in a way a dead aviator or a crippled machine is far more dangerous to life and limb than one flying overhead."[1]

"Like all novices, we began with the helicopter (in childhood) but soon saw it had no future and dropped it. The helicopter does, with great labor, only what the balloon does without labor, and is no more fitted than the balloon for rapid horizontal flight. If its engine stops, it must fall with deathly violence, for it can neither float like a balloon nor glide like an aeroplane. The helicopter is much easier to design than an aeroplane, but it is worthless when done."[2]

Obviously aircraft performance has improved since Harper's and Wright's observations, but man's abilities to survive a crash remains the same. In the days of open cockpits and cabins, seat belts were installed to keep aviators from falling out of their machines. With development in this and other areas of aviation, seat restraint systems and features such as crashworthy or energy absorbing structures have taken their place in the automobile industry as direct spinoffs from aviation. With man as the limiting factor, what must be considered is a balance.

1 Harper's Aircraft Book, 1913

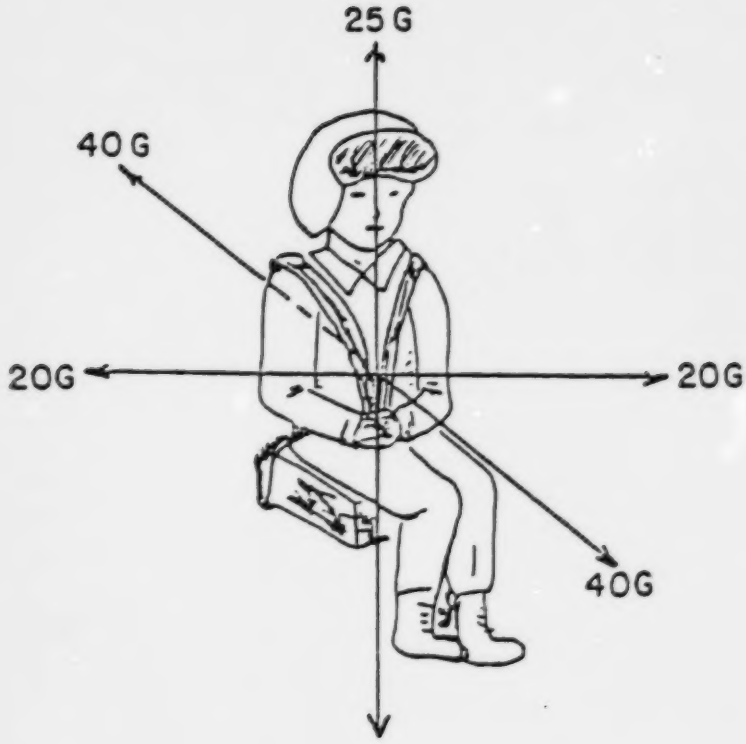
2 Wilbur Wright, January 15, 1909

Safety, which is defined as absence of risk, is not achievable given that man wishes to travel at speeds and go to locations where his feet will not carry him. Once man is at a speed in excess of twenty (20) mph or at a height greater than ten (10) feet, he is at risk of injury or worse. If these two (2) factors (speed and height) are combined as they are in flight, the risk increases and the problem becomes one of how safe or how minimal the risk can be made.

The first step in the process is to realize that despite all the efforts of man, aircraft (fixed and rotary wing) will still crash. Even with the best trained crews and the most sophisticated equipment, fatalities occur in what are defined as survivable accidents. The Crash Survival Design Guide Volume II defines Crashworthiness and "human tolerance levels" as follows:

"Crashworthiness may be defined as the ability of basic aircraft structure to provide protection to occupants during survivable impact conditions. Impact conditions are considered survivable in that part of the cabin area where the crash forces exist are within the limits of human tolerance and where surrounding structure remains reasonably intact. Although the crash force in most accidents is applied in a direction oblique to the flight path, it is customary to resolve vertical and horizontal components of the crash force resultant and relate these to the human tolerance levels, either parallel or transverse to the spine. A normally seated person, when effectively restrained, can tolerate with minimal or no injury approximately forty-three (43) G transfers to the spine, twenty-five (25) G parallel to the spine in the foot to head direction (positive G), fifteen (15) G parallel to the spine in the head to foot direction (negative G), and twenty (20) G side to side (lateral as summarized in Figure 1)."[3]

3 Aircraft Crash Survival Design Guide - Volume II, U.S. Army Research and Technology Laboratories, 1980



Human Tolerance to Acceleration
(Effectively Restrained)

Figure 1

In simple terms, G is a measure of acceleration. For example, a pilot flying a fighter aircraft experiences G whenever he turns his aircraft as does a passenger to a lesser degree in any aircraft which turns. This G force is in the vertical plane. If two (2) G is applied the body experiences forces on its structure and components (organs) equal to twice their normal weight in the vertical axis while turning.

The forces depicted above show the basic limits of the human body to accelerative forces in the seated restrained position. Because helicopters fly over rough terrain, a pilot may not have much effect on the deceleration forces on landing. Three (3) factors dictate the success of any forced landing:

1. Landing environment
2. Aircraft design
3. Skill and technique of the pilot

A pilot forced to land a helicopter next to a cliff being beaten by forty (40) foot waves has little or no chance of a successful landing. A pilot landing a non-float equipped helicopter with a low slung tail assembly on any water surface has little hope of a successful landing. In these scenarios, impact deceleration forces or blade strike induced decelerating forces may exceed human limits.

The gyration and body action associated with aircraft crashes are extremely violent. Although flailing of the body parts is much more pronounced when a lap belt only is utilized, multi-directional flailing of the head, arms, and legs is quite considerable even with a proper shoulder restraint system. Space for occupants is usually at a premium in helicopters. It is usually not feasible to remove items such as structural members which may become involved with impacts with bodily parts during a deceleration. Some steps must be taken therefore to minimize the injury potential by redesign and by careful application of padding, and in some cases by the use of additional protective equipment such as helmets. The environmental hazards in general consist of primary, secondary and tertiary hazards:

Olaf W. Skjenna in "Cause Factor: Human"[4] defines these hazards as follows:

1. Primary Hazards

   Primary environmental hazards are those rigid or semi-rigid structural members within the extremity envelope of the head and chest.

2. Secondary Hazards

   Secondary environmental hazards are those that could result in trapping or injuring the lower extremities to the extent that one's ability to escape rapidly would be compromised.

3. Tertiary Hazards

   Tertiary environmental hazards are those rigid and semi-rigid structural members that could cause injury to flailing upper limbs to an extent that could reduce one's ability to operate escape hatches or perform other essential tasks.

Much work has been done in the past ten (10) years to improve and reduce the lethal environment in automobiles by modifying such structures as dashboards, protruding objects, knobs, and padding the dashboard with impact absorbing materials. Unfortunately for the aircraft pilot and passengers, an equivalent amount of redesign has not been applied to the lethal environment of the interior.

4 Cause Factor: Human, A Treatise on Rotary Wing Human Factors, Skjenna, O. W., 1981

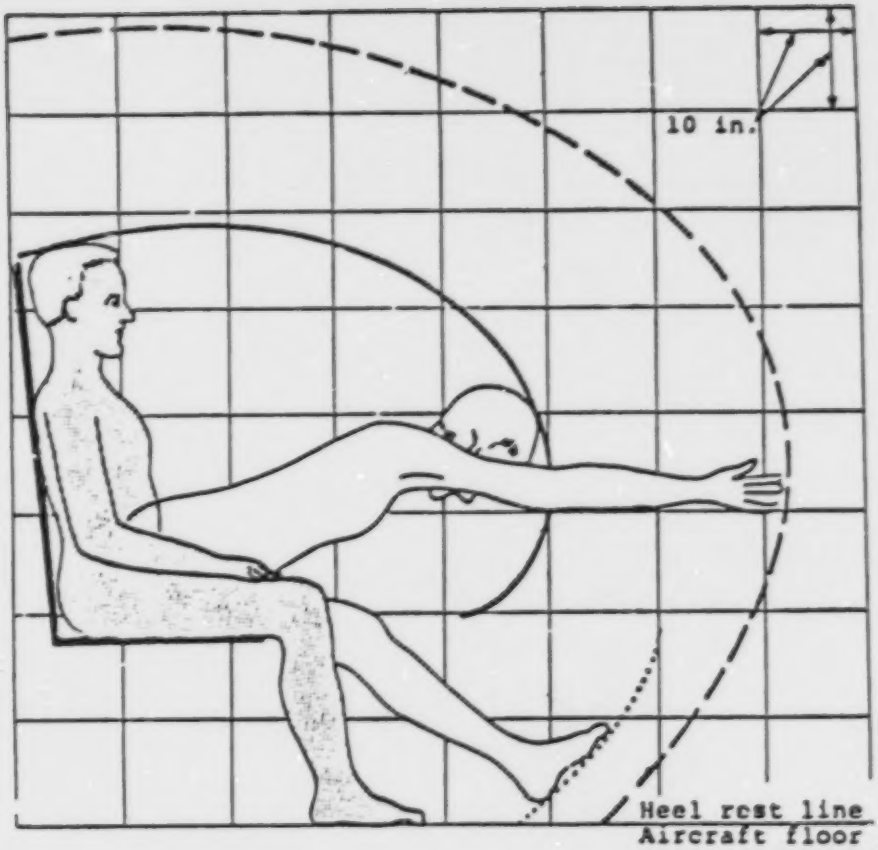
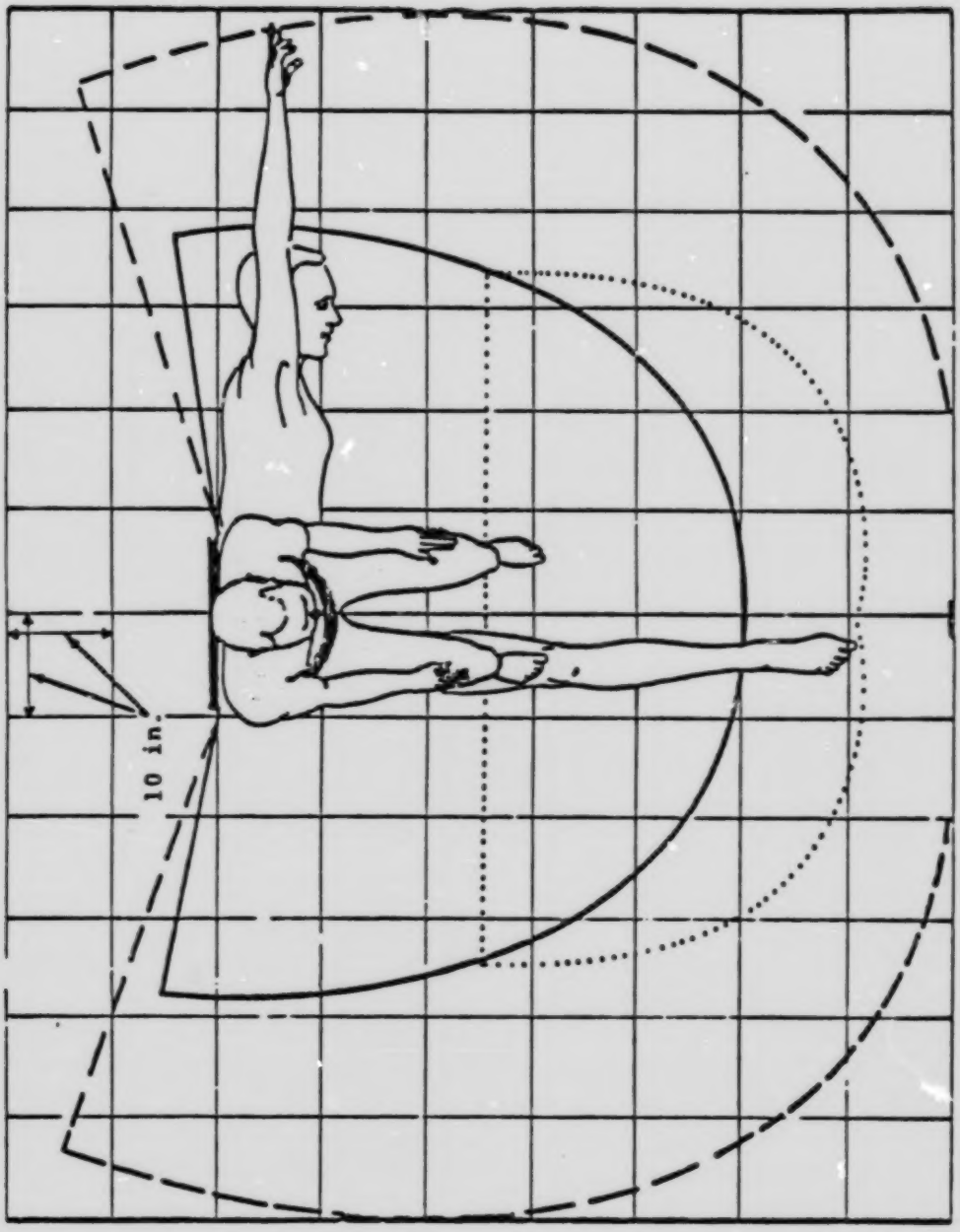
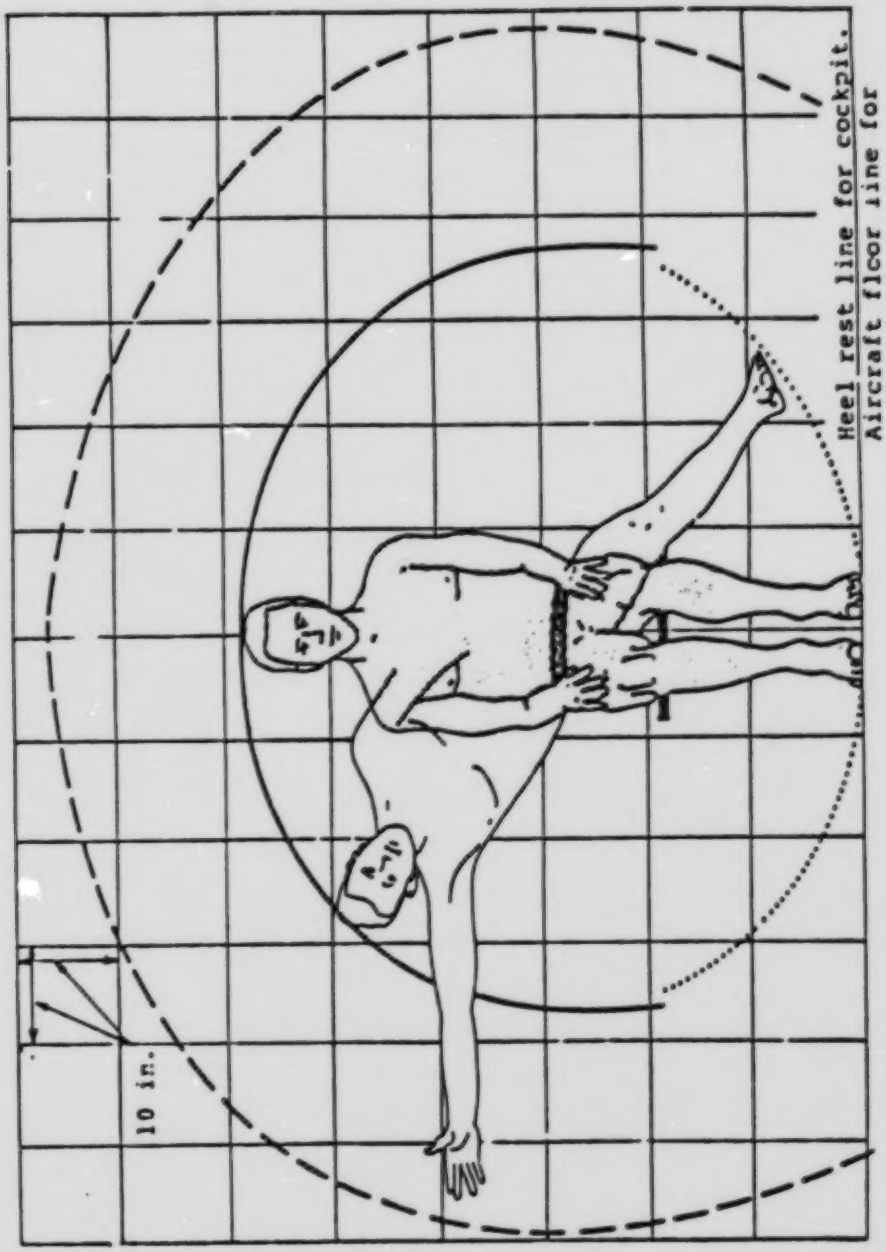


Figure 2 - Lap-belt-only extremity strike envelope - side view



Lap-belt-only extremity strike envelope - top view.

Figure 3



Lap-belt-only extremity strike envelope - front view.

Figure 4

"Cause Factor: Human"[5] states that contact injuries result from forceful contact between the occupant and the cabin structure, or objects within the cabin. The three (3) most common injuries in survivable accidents are lacerations, fractures, and burns. Aside from injuries to the back, ranging from strain and bruising to compression fractures, most body injuries result from flailing and tend to be located peripherally:

Upper limb	- 22%
Lower limb	- 20%
Back	- 13%
Head	- 11%
Face	- 10%
Chest	- 8%
Generalized	- 6%
Abdomen	- 4%
Neck	- 4%
Pelvis	- 2%

The causes of death in survivable accidents are summarized as follows:

Burns and complications	- 30%
Multiple extreme trauma	- 18%
Head injuries	- 15%
Hemorrhage and shock	- 9%
Heart/great vessel trauma	- 9%
Hemopneumothorax	- 8%
Chemical Pneumonia	- 8%
Drowning	- 3%

In non-survivable accidents, the major cause of death is multiple extreme trauma, often complicated by fire. Head injury is the second most important cause of death.

To summarize, if the impact is within human G tolerance levels and a seated person is properly restrained, survival is possible if your immediate environment does not collapse on you. Other factors such as loose objects may cause difficulty and in one case a crew man in a helicopter was killed in a very hard landing by a thermos bottle. Further, if the occupants of a helicopter do not brace for an impact, their chances of injury are increased as they may be thrown about as indicated in the Lap Belt Only Extremity Strike Envelope figures.

5 Cause Factor: Human, A Treatise on Rotary Wing Human Factors, Skjenna, O.W., 1981

The occupant of a helicopter must now face the problems facing him or her in the post crash period. The post crash period commences immediately following impact, rebound, pulse of impact and rolling over. The post crash scenario involves two (2) major areas, one (1) being escape, the other fire. Approximately thirty percent (30%) of deaths in survivable accidents are due to burns. The United States Army Board of Aviation Accident Research found post-crash fires occur at the following rates:

9% light helo	4 - 6 pax
33% medium helo	utility 8 - 10 pax
82% heavy helo	multi pax-cargo

Because of the post-crash fire hazards in helicopters and the fact that the majority of injuries and fatalities that occur from all types of accidents are forms of thermal injuries, emergency escape provisions should be thought of primarily in terms of the post-crash fire threat. The major considerations when dealing with emergency escape consist of emergency exits themselves, access to the emergency exits, and emergency lighting, particularly in larger cargo and passenger carrying helicopters. It must be remembered that the post-crash environment is usually very confusing, frightening, and that panic may be a major factor, particularly if a post-crash fire occurs.

The "Crash Survive Design Guide"[6] classifies exits into three (3) categories:

(1) Class A Exit: Doors, hatches, canopies or other exit closures intended primarily for normal entry and exit.

(2) Class B Exit: Door, hatches or other exit closures intended primarily for service of logistic purposes.

(3) Class C Exit: A window, door, hatch or other exit closure intended primarily for emergency evacuation.

6 Aircraft Crash Survival Design Guide - Volume V, U.S. Army Research and Technology Laboratories, 1980

Exit enclosures for Class C exits must be capable of being removed from the exit opening within five (5) seconds regardless of the aircraft's attitude. The Class constitutes the minimum requirement for an emergency exit. A Class A exit with emergency jettison provisions is normally considered to be superior to Class C exit.

It has been recommended that Class C exits should be at least twenty-two (22) inches square, with six (6) inch radius corners which allows evacuation at the rate of 1.5 seconds per man. If with a particular helicopter, the design does not lend itself to an exit of this size and shape an alternate size and shape can be used providing that the exit can handle a large man dressed in winter flight or field clothing at the rate of 1.5 seconds per man. For helicopters with a single crew position one (1) Class A exit and one (1) Class C exit on the opposite of the cockpit should be provided, assuming that a sliding or clam shell type canopy is not used. The rationale for this is to provide an alternative means of escape if the aircraft rolls on its side and an exit becomes blocked. With side-by-side crew position cockpits, at least two (2) Class C exits should be provided, one (1) on each side of the fuselage. With this arrangement, any combination of Class C and Class A exits may be substituted provided the Class A exits have an emergency jettison feature. With tandem crew position helicopters such as the Huey Cobra, the minimum requirements should be two (2) Class C exits and one (1) Class A exit with an emergency release provision, assuming the two (2) crew positions are mutually accessible. This means that a ninety-nine (99) percentile crew member dressed in winter flight clothing could, without undue difficulty, climb from one crew position to the other in order to exit the aircraft in an emergency. The minimum emergency escape exit requirement for the passenger sections should be two (2) Class C exits, one (1) exit installed on each side of fuselage. In helicopters with engines, transmissions, major controls, etc., located over personnel compartments bottom and/or aft exits could be substituted for overhead exits.

Exits intended for emergencies should be equally divided on each side of the aircraft and, if feasible, should not be directly opposite each other because of the probability of crowding in one particular area. In addition, the exits should be exposed to the least distortion and provide maximum accessibility to occupants following a crash. They should be located as far away from external hazards such as propellers, turbine engines inlets, armament, etc., and as far away from fuel spillage areas and from major ignition sources as possible. All exits used for the emergency exit should be capable of being opened by rescue

personnel from outside of the aircraft. The release should be designed so that it can be opened quickly from the inside or the outside by one person using one hand, and no secondary operations such as moving or unlocking locks, catches, stops, bolts, etc., is necessary. The exit release handles should be located in such a manner that they will not snag clothing and so that it is not necessary for occupants to unlock their shoulder harnesses in order to turn the handles. This is important primarily because it is sometimes desirable to release emergency exits prior to crash impact, as in water crash landings. All crew members and passengers should be briefed before take-off on operations of the exits, and the method of removal should be obvious and natural to all persons on board the aircraft.

Access from aisles to all types of exits must be provided so that the exits will not be obstructed by any seats, litter installations, etc. In helicopters with a wide fuselage, such as the Chinook, problems have been encountered when the helicopter is lying on its side, in reaching an exit on the other side as the height of the exit may be beyond the reach of the occupants in the aircraft.

Emergency lighting capable of being operated manually or activated automatically at impact should be provided for reading exit operating instructions and for lighting the exterior of the aircraft to illuminate exits and paths of escape and to serve as a crash locator beacon. Experimentation by N.A.S.A. and other agencies has shown that following an aircraft crash the air immediately becomes contaminated with dust and/or smoke leading to disorientation of the passengers which would likely result in panic. Emergency lighting, therefore, can become critical. Emergency lighting power sources should be independent of the main electrical system of the helicopter and should sustain effective illumination for at least fifteen (15) minutes.

Studies of accident records indicate that the greatest number of fatalities occur in accidents involving post-crash fire. In helicopters, post-crash fire is a major threat due partly to the tendency for flammables and ignition sources to be located in close proximity as a result of centre of gravity limitations. It must be borne in mind that aviation fuel does not constitute the only combustion hazard and that oil and hydraulic fluid may be responsible for initiation of the post-crash fire if ignition sources are present. Although oil and hydraulic fluid is difficult to light in puddles, the mists or vapors are highly flammable and often substances such as lubricating oils are preheated as a result of normal aircraft operations. In addition, hydraulic fluid is usually under pressure and, should a hydraulic line be severed, a highly inflammable or explosive mist may result. In the investigation of a fire accident,

combustible cargo must also be considered. Upholstery, although not usually the primary ignition source, decreases the burn-through times of fuselage due to its insulating properties and provides a good flame path of fire propagation. The ignition sources in a post-crash fire consist of:

1. Flames

   Flames may provide the primary ignition sources and the result in engines or from oil hydraulics.

2. Hot Surfaces

   These include brakes, heaters, bulbs, nickel-cadmium batteries, etc.

3. Electrical Sparks

4. Friction Sparks

5. Static Sparks.

Many studies have been performed where aircraft and helicopters were crashed and allowed to burn. In these studies it was found that the time taken to reach the limits of human tolerability, based on the respirator heat tolerance of 390 Fahrenheit, was around 120 seconds for large passenger or cargo fixed-wing aircraft, and varied between six (6) to fifteen (15) seconds for utility-cargo type helicopters.

The human tolerability in post-crash fire depends upon two (2) factors:

1. Heat

2. Toxic gases resulting as by-products of combustion. The most obvious toxic by-product of combustion is carbon monoxide. A carboxyhemoglobin percentage of thirty-five percent (35%) is sufficient to produce disorientation, collapse and fainting, and could be considered a tolerance limit as far as escape from a burning aircraft is concerned. A level of sixty percent (60%) can result in unconsciousness, respiratory

failure and death in long-term exposure. Forbes, Sergeant and Roughton in a paper in the American Journal of Physiology stated the following:

$$COHB = K \times CO \times T$$

When:

COHB is the percentage of carboxyhemoglobin formed,

CO = the percentage of carbon monoxide in the air,

T = exposure time in minutes,

K = absorption constant.

The absorption constant K depends upon the ventilation rate of the exposed persons. The constant K is equal to three (3) for persons at rest, five (5) for light activity, eight (8) for light work, and eleven (11) for heavy work. A likely value for K during a post-crash escape is eight (8). Therefore, an individual will reach the escape limiting thirty-five percent (35%) COHB level when he breathes three percent (3%) carbon monoxide for ninety (90) seconds.

Table 1
TOXIC GASES PRODUCED BY BURNING AIRCRAFT MATERIALS
(In Addition to CO_2)

ITEM	HCl	SO2	BENZENE	UNSATURATED HYDROCARBONS	NO2	HCn	C12	ARSINE	PHOSGENE	HF
ACRYLIC	----------	----------	----------	NONE	----------	----------	----------	----------	----------	----------
LATEX FOAM	X	X	X	X						
LEATHER		X			X	X	X			
MINERAL WOOL					X					
MODACRYLIC	X	X		X		X				
POLYEROTHENE FOAM				X						
PLYWOOD				X				X		
SIMULATED LEATHER				X					X	
VINYL FOAM			X	X						
WOOL		X				X				
POLYVINYL FLUORIDE	X									X
URETHANE						X				
ABS						X				
POLYSULFONE		X								
RUBBER		X								

Table 1 shows the toxic gases produced by burning aircraft materials in addition to carbon monoxide and carbon dioxide. It is therefore obvious that careful consideration must be given when choosing materials for upholstery, seat cushions, etc.

In an overwater ditching scenario, there is rarely a problem with post-crash fire. Instead, the occupants of a helicopter are faced with a number of other problems.

If the ditching itself is survivable (i.e. the impact forces), then the survivor must effectively egress the helicopter since the average helicopter will likely sink over a period of time. This period of time relates to the physical integrity of the helicopter itself (i.e. post-impact), the sea state, design features to keep the helicopter afloat while on the water and the incorporation of auxiliary floatation. Auxiliary floatation systems come in many different types and styles depending on the helicopter using them. Needless to say, if all of these factors fit properly into place at the time of ditching, the helicopter stands a reasonable chance of remaining upright, at least until the passengers and crew egress into the water and into their liferafts.

When the survivor departs the helicopter, there are two major considerations that must be addressed. The first is whether the survivor is properly dressed to endure the dangers of water survival. Today's standards in suit design ensure that the survivor has a very good chance of initial survival if wearing a properly fitted and designed immersion suit.

The second consideration is the survivor's access to the liferaft and to a lesser extent, the physical qualities of the liferaft itself. Since every scenario is different, one has to look at some of the worst possibilities when considering access to the liferaft. When one is located in the cabin of the helicopter, it allows easy access in controlled, upright ditching. If the helicopter floods and possibly inverts, then the survivor has a major problem in extracting the liferaft from the cabin during the initial phases of escape. This is a very difficult manoeuvre in any scenario and will likely result in the survivor's inability to extract the liferaft from the cabin.

Once an accident has occurred, either on land or water, there is a requirement to conduct investigations to determine a cause and hopefully prevent these situations form recurring. Our method of gathering more precise data on the operation of the helicopter prior to and during the accident is through the use of both cockpit voice recorders and flight data recorders. The current regulations governing the use of Cockpit Voice Recorders and Flight Data Recorders cover the fixed-wing or aeroplane operation, however, it remains up to individual operators to install these data recorders in helicopters.

2.0 BACKGROUND (Cont.)

In Canada, we have witnessed the need for better post-accident information and the value of such devices is therefore relatively obvious. From an operators point of view there remain two major considerations with regard to their installation in helicopters. One is the initial cost and subsequent maintenance to ensure their proper operation if ever needed. The second relates to the regulations which do not require the use of these devices and therefore an operator is within the letter of the law when operating without them.

3.0 SAFETY ENHANCEMENTS

3.1 STRUCTURES:

3.1.1 Related Accident Data:

"The Canadian accident rate"[7] (the number of aircraft accidents in Canada per 100,000 flying hours) has steadily decreased from 19.1 in 1976 to an estimated 13.5 in 1986. The reduction in the accident rate has been accompanied by a decreased in the fatal accident rate (see table 1).

Table 1 - Canadian Accident Rates 1976 - 1986

	Accident		Accident Rate per 100,000 Flying Hours	
Year	Total	Fatal	Total	Fatal
76	699	89	19.1	2.4
77	693	81	18.8	2.2
78	696	93	17.7	2.4
79	726	109	18.3	2.8
80	684	76	16.0	1.8
81	695	88	16.9	2.1
82	539	62	14.6	1.7
83	510	63	14.8	1.8
84	458	57	13.8	1.7
85	438	39	13.0 (est.)	1.2
86	472	66	13.5 (est.)	1.9

These statistics are evidence that the many factors at work in preventing accidents, from safety education programs to technological improvements, are having a positive effect.

However, the accident statistics also indicate that the crashworthiness of aircraft has not improved in the past decade. During this period, the percentage of accidents which result in fatalities and the average number of fatalities per accident remained essentially constant (see Table 2). In short, while fewer accidents occur now than a decade ago, the chance of surviving if an accident occurs has not significantly improved.

7 Study of the Influence of Shoulder Harnesses in Aviation Safety, Canadian Aviation Safety Board, 1987

3.1.1 Related Accident Data (Cont.)

Table 2 - Percentage of Accidents with Fatalities

Year	Percentage	Fatalities per Fatal Accident
76	12.7	2.0
77	11.7	2.2
78	13.4	2.6
79	15.0	2.3
80	11.1	2.0
81	12.7	2.0
82	11.5	2.0
83	12.4	2.3
84	12.4	2.1
85	8.9	1.8
86	14.0	1.7

3.1.2 Developments:

"Cause Factor: Human"[8] states the most critical factor concerning survivability in a helicopter crash is referred to as the Container. Since one must break eggs to make an omelet, the best source of information is crash data. The Crash Survival Investigators School at Arizona State University has defined some parameters for containers. The container or occupiable volume of the helicopter should be evaluated with respect to soil plowing tendencies, energy absorbing properties of the structural members, and ability to maintain volume during the deceleration.

An important concept is that little sacrifice must be made in terms of weight to provide better crashworthy design. Rather than actually strengthening fuselage members, the ideal is to absorb energy from an impact in a predictable, controllable fashion. For this, various load limiting devices and members, made of ductile material, provide an advantage. The shape of the fuselage cross section is also of importance. Haley has shown that the circular cross section type of structure offers much more resistance to crushing in an impact as compared to a

8 Cause Factor: Human, A Treatise on Rotary Wing Human Factors, Skjenna, O.W., 1981

3.1.2 **Developments** (Cont.)

rectangular type structure. Little imagination is required to appreciate that if a square box is dropped on its corner it will probably fracture, whereas if a barrel is dropped from the same height it will probably remain intact. The ideal design for the cross section of a helicopter fuselage, therefore, would be circular or egg-shaped with load-limiting devices between the belly and the floor of the aircraft to absorb energy before it is transmitted to the occupant. The energy absorbable material might be honeycomb material or ductile longitudinal beams in the floor.

3.1.3 **Industry, Academic & Regulatory Recommendations:**

The following recommendations regarding improved fuselage design for occupant protection are derived from the "Crash Survival Design Guide"[9]:

1. Helicopters should be designed to withstand lateral impact on a rigid surface such as concrete with a velocity change of thirty (30) feet per second. The aircraft should provide the required degree of protection for crashes in which the fuselage rotates plus or minus twenty (20) degrees about its yaw axis.

2. In vertical impacts of rotary winged aircraft, almost all of the kinetic energy on impact is absorbed in fuselage and landing gear structure. Considering this, the aircraft should be designed to withstand vertical crashes onto a rigid surface with impact velocity changes of forty-two (42) feet per second. The aircraft should provide the required degree of protection for crashes in which the fuselage rotates plus or minus fifteen (15) degrees about its pitch axis and plus or minus 30 degrees about its roll axis.

9 Aircraft Crash Survival Design Guide - Volume III, U.S. Army Research and Technology Laboratories, 1980

3.1.3 **Industry, Academic & Regulatory Recommendations** (Cont.)

3. Rotary winged aircraft should be designed to withstand a crash containing a 50 foot per second resultant velocity change. This plus all combinations of longitudinal and vertical components vectorially summing to 50 feet per second or less, with vertical velocity components up to and including forty-two (42) feet per second. It includes all combinations of longitudinal and lateral components vectorially summing to fifty (50) feet per second or less with lateral components up to and including thirty (30) feet per second.

4. In order to provide living space for the crew members during some reasonable frontal crash environment, rotary wing aircraft should be designed to withstand a longitudinal impact into a rigid wall or barrier with an impact velocity change of twenty (20) feet per second.

5. The fuselage and landing gear should be so constructed that the effect of terrain contact after antitorque loss is minimized; specifically, helicopters should be designed to impact sod type of terrain at sixty (60) knots airspeed, eight (8) feet per second sinkspeed, twenty (20) degree yaw, ten (10) degree roll, and twenty (20) degree nose-up pitch without turning over. Should the helicopter turn over under these conditions, the fuselage container should remain essentially intact for a minimum of two (2) 360 degree rolls.

The indices of crashworthiness which have been proposed include:

(a) the degree of cabin collapse;

(b) the level of deceleration experienced by occupants during the crash.

3.1.3 **Industry, Academic & Regulatory Recommendations** (Cont.)

To increase fuselage crashworthiness and meet the above criteria, the following changes should be made:

1. Increase the energy absorption capacity of the structure surrounding the occupiable areas.

2. Modify structures such as the antitorque rotor tail boom etc., to ensure that if these parts fail they fail safely.

3. Reinforce the cockpit and cabin structure.

4. Modify the fuselage structure to allow increased deformation or collapse of structures in unoccupied areas.

3.1.4 **Conclusions:**

Research and technology have greatly contributed to the crashworthiness of a helicopter fuselage. Most modern helicopters now incorporate various degrees of this technology with little performance sacrifice.

3.1.5 **Equipment Availability:**

Modifications are available on particular aircraft to improve fuselage crashworthiness such as improved landing gear absorption devices. Some manufacturers offer a range of crashworthiness options. However, crashworthiness of a fuselage is a design feature and consequently should be considered when selecting a type of helicopter.

3.2 SEATS:

3.2.1 Related Accidents:

UNITED STATES ARMY HELICOPTER ESCAPE/
SURVIVAL NARRATIVES - CALENDER YEAR 1983

CH-53D

During cross country flight, tail rotor assembly departed aircraft. Aircraft entered autorotation and descended in 180 degree turn. On impact an explosion occurred and fire engulfed the aircraft. One passenger survived, other six (6) occupants fatal. Crash forces were later determined to be survivable based on absences of decelerative injuries, spinal fractures or transections of any major blood vessels. Pilots' seats detached on impact and both were killed instantly by blade strike. Passengers in forward portion of cabin were killed immediately from collapse of transmission and shifting cargo. One passenger located far aft on left and crew chief located forward on right survived impact, but crew chief's minor injury may have slowed his egress and he was unable to escape the post-crash fire, dying from thermal burns. The surviving passenger was sitting unstrapped in the troop seat on the left aft during impact. He stumbled from the rear of the wreckage down the ramp and out of the flames sustaining third degree burns of the face, scalp, hands and legs encompassing thirty-five percent (35) of his body surface. The wingman landed and picked up the survivor and searched the area for other survivors before leaving.

3.2.2 Developments:

Improvement of fuselage energy absorption capabilities need not necessarily mean a sacrifice in weight, as components may be designed to deform in a controlled and predictable way, and load limiting devices such as longesron supports may be utilized. Ideally, the cabin area can be strengthened to some extent as long as the materials used are not excessively brittle or easily fractured, resulting in further environmental hazards.

3.2.2 **Developments** (Cont.)

Using the principles of crash kinematics for determining the G loading on occupants, it is obvious that the G loadings are directly proportional to the square of the velocity at impact and inversely proportional to the stopping distance. Since the velocity at impact often cannot be controlled, the only controllable variable therefore is stopping distance (S). Aside from deformation of the fuselage itself, the only other main modification is in the application of these principles to the occupant's seat. Therefore, the utilization of energy-absorbing materials in seat cushions, for example, and load limiting devices becomes important.

A multitude of devices have been proposed, developed and tested for absorbing energy and limiting loads. The kinetic energy of the moving mass may be absorbed by applying forces over a distance; this is the primary mechanism for absorbing crash energy. Energy absorbing mechanisms should stroke at loads tolerable to human occupants and should provide stroke distances consistent with these loads and with the energy to be absorbed. Various studies have shown that plastic deformation of materials, primarily metal, results in a reasonably efficient energy-absorbing process, and consequently most load limiting or energy absorbing devices use this principle. The criteria for efficient energy absorbers are as follows:

1. The device should provide a predictable force versus deformation trace.

2. The rapid loading rate expected in crashes should not cause significant change in the force versus deformation characteristics of the device.

3. The assembly in which the device is used should have the ability to sustain tension and compression.

4. The device should be as light and small as possible.

5. The device should be economical.

3.2.2 **Developments** (Cont.)

6. The device should be capable of being relied upon to perform satisfactorily throughout the life of the aircraft without requiring maintenance.

One type of device which has been extensively tested is an aluminum tube which inverts when loaded. This tube was first developed for use in automobile steering wheels and was used as a front seat compression leg for an airliner seat in experimental seat tests for N.A.S.A. It provided a vertical deformation of 5.5 inches at a controlled load and although lateral forces caused the inverting tube to be distorted from a circular to an elliptical shape the device still performed satisfactorily.

Special attention must be paid to the seat cushions in helicopters; these should not only provide comfort and vibration damping for the occupant but must also be capable of absorbing vertical energy in impact situations. The material certainly should not increase the decelerative levels to the occupant's spine due to dynamic overshoot as a result of elastic rebound. For this reason foam cushions are not recommended. More suitable materials such as those described under energy absorption, or even styrofoam should be employed in the construction of seat cushions. Helicopters which have not employed load-limiting devices, or where important structures are found beneath the seatpan, should be retrofitted with cushions manufactured of energy absorbing materials.

3.2.3 **Industry, Academic & Regulatory Recommendations:**

The CAA Harp report concluded that:

"It seems generally agreed that helicopters when they do crash cause unavoidable injury (often fatal) to the passengers and crew.

3.2.3 Industry, Academic & Regulatory Recommendations (Cont.)

Seat integrity is inadequate and in too many cases fuel tanks disintegrate and cause major fires."[10]

There is a major program for military helicopters in United States which involves considerable increase in structural strength and energy absorption ability but we do not feel that the weight penalty this involves would be justified for civil transport. We have seen some ingenious a low weight devices for absorbing energy in seats (by elastic deformation of steel rods), but we appreciate that items cannot be considered in isolation. We believe that there is a case for raising the energy absorption capability of the landing gear (and ensuring that it entrains no consequential harm when it fails), designing and then testing the structure of new helicopters to optimum energy absorption capability and increasing the attachment strength and then absorption capability of seats; our American friends refer to the need to 'delethalise' seats, which we support. We have been told that major benefit could come from adequate seat belt restraint, using diagonal straps as on a car (but anchored to the seat); we can readily believe this but cannot comment on the weight penalty, which might be severe. There must be scope for ingenuity here.

The Harp Report further recommended that:

"A study should be initiated forthwith to identify suitable requirements for an improved standard of crashworthiness of the structure as a whole, landing gear, seats and possible restraint systems, having regard to possible military-civil cooperation in this area."

10 Review of Helicopter Airworthiness, CAA HARP Report, 1984.

3.2.4 Conclusions:

Impact absorbing seats greatly contribute to the occupant's survival in a survivable crash assuming the fuselage volume remains in reasonable condition. Ideally these seats are used in conjunction with other energy absorbing devices designed into the aircraft.

3.2.5 Equipment Availability:

Most helicopter manufacturers offer energy absorbing seats as an option. The cost, weight penalty for such an option has to be considered on an individual aircraft type. However, given the competitive nature of commercial helicopter operations, the cost of the option generally prohibits the operator from using these seats unless requested or required by the user. It should be noted that all seats installed by a manufacturer must conform to minimum crashworthy standards. If you are willing to pay more, there are passenger seats available which will provide greater impact resistance.

AS 332L Super Puma:

Aerospatiale who manufactures the Super Puma offer a variety of crashworthy seats. The two types of optional seating which can be configured in different variations for the Super Puma are as follows:

A) Passenger (Comfort Seats)

This version is made up of 17 seats installed with safety lap belts.

Source:
- Aerospatiale, France
- Aero-Seat & Systems Inc., Dallas, Texas

Cost Per Unit:
- Aerospatiale, $1,400 US
- Aero-Seat & Systems Inc., $1,400 US

3.2.5 Equipment Availability (Cont.)

B) Lateral Troop Seat

This installation enables 16 passengers to be carried in the Super Puma cabin.

The troop seats, laid across the cabin, are hung on a longitudinal removable rail which is screwed up to a fixed structural point (for each seat) at the upper part of the cabin.

Each seat is made up of a fabric cover stretched across a rigid tubular frame and a fabric back also stretched across a tubular frame.

This structure includes two energy absorbers at the upper part attached to the cabin ceiling by means of a quick-fit tensioning system. The seat part is secured to the cabin floor by two energy absorbers and six cables which stabilize the assembly. For quick-release fixtures are provided on the floor.

This seat which can be folded is fitted with an adjustable waist belt and an inertia-reel harness. This installation calls for the use of the crashworthy floor.

Source: - Aerospatiale, France

Cost
Per Total Kit: - $72,928 US

Bell 212 Crashworthy Seat:

Source: - Aero Seats & Systems Inc.

Cost
Per Unit: - High back, 4-point harness - $3,300 US

Sikorsky S-61N Crashworthy Seat:

Source: - Aero Seats & Systems Inc.

Cost
Per Unit: - High back, 4-point harness - $3,300 US

3.2.6 Factors Phase 5 Lateral Seating:

Survival Systems has completed Phase 5 which is the lateral seating arrangement based on the AS332L Super Puma crashworthy troop seating configuration previously discussed.

Five seats were installed in the modular egress training system facing outboard to the port side. Each seat was equipped with a standard aviation lap belt which was used in previous phases of study. A standard super puma push-out window with pull tab seal was located midway between the remaining two aft seats.

Thirty-two subjects ran through seven sequences. The first sequence was not evaluated but was used as a familiarization sequence for the subject. The remaining six of the sequences were monitored by qualified underwater escape instructors and evaluated as to a pass or fail. A questionnaire was also included with details of any problems encountered.

There were three variations of escape set up:

- Sitting in the furthest aft seat with the window in place;
- Sitting in the most forward seat with an open exit; and
- Sitting in the furthest forward seat with the window exit in place.

Each subject was given a briefing utilizing a Super Puma boarding card on such items as functioning the exit release mechanism, jettisoning the exit and a crash position to be assumed. For reasons of control, each subject was told to assume the same type of crash position.

3.2.6 Factors Phase 5 Lateral Seating (Cont.)

Preliminary Observations:

- When a subject moved laterally in the wrong direction, he or she would not likely recover from the mistake;

- On releasing the lapbelt, a large number of the subjects arched over backwards never finding the exit. The arch coincided with the direction of the roll;

- Unless the subjects slid sideways on the seats toward an exit area, they were likely to experience disorientation do to the lack of physical referencing; and

- Sitting directly across from an exit with window in place did not necessarily guarantee success. As shown in the accompanying graph, a higher success rate was encountered from a position four seats forward from the exit position. The window was out in this sequence.

Concerns:

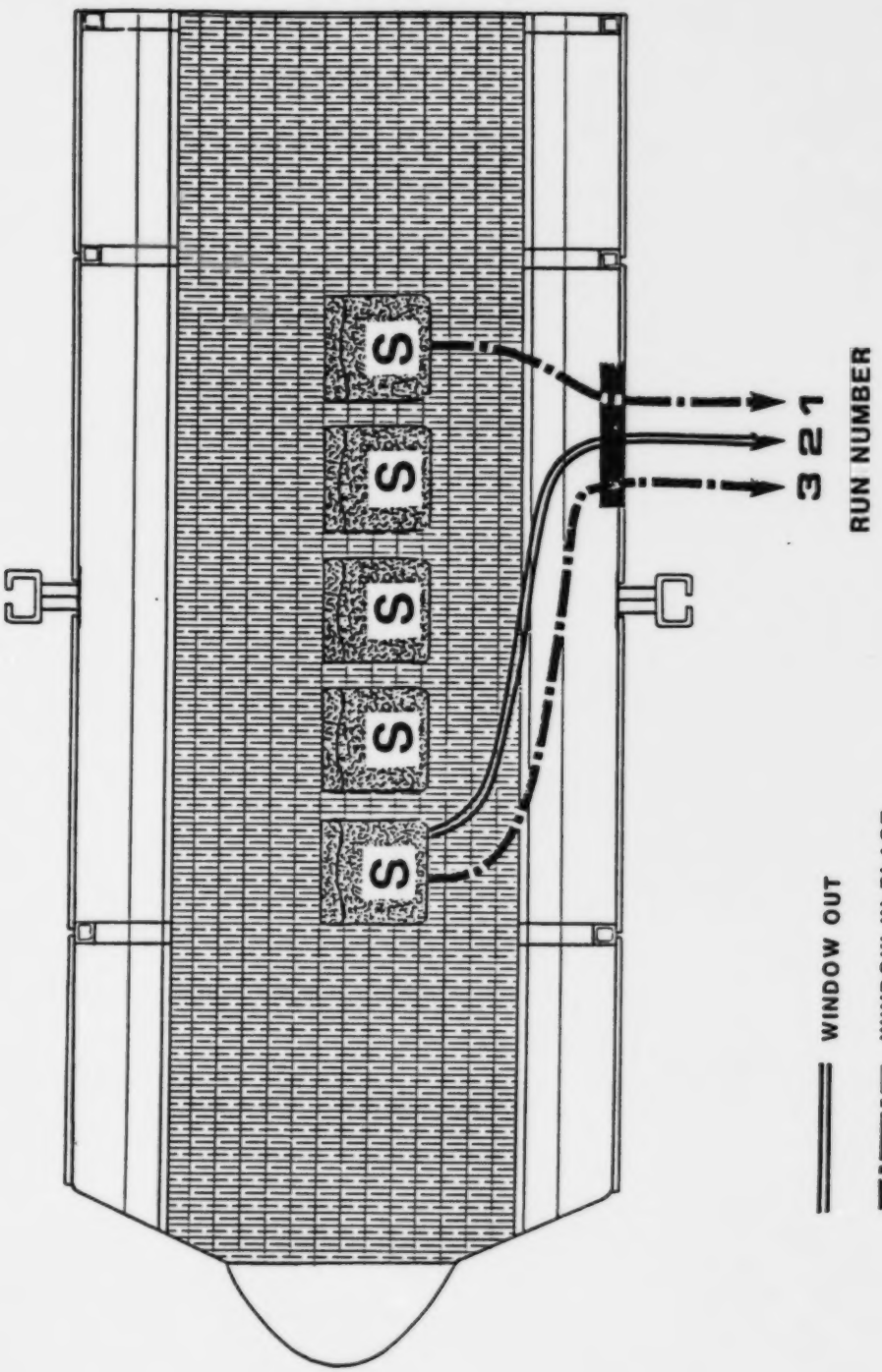
- It would be extremely difficult, if not impossible, for a passenger to orientate to an alternate exit located behind due to the webbing that would be encountered which is a part of the troop seat installation.

  This scenario could occur if the aircraft was lying on its side in shallow water.

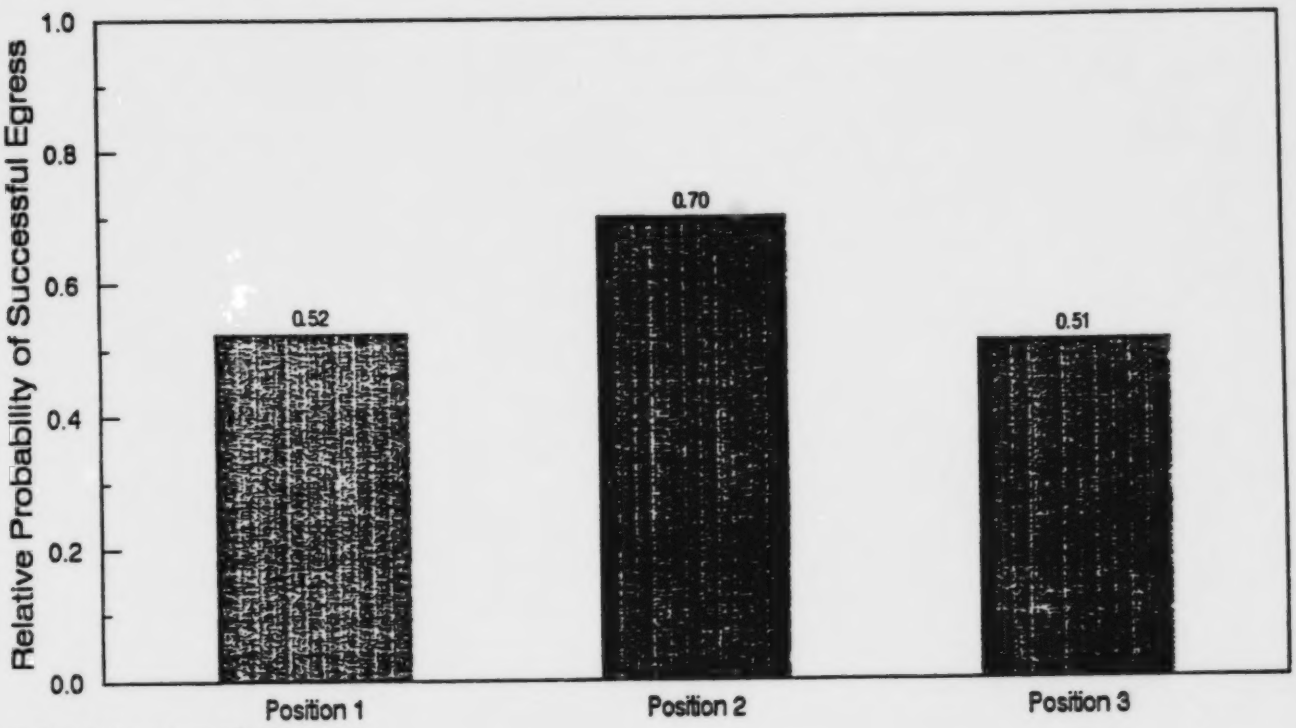
- Dr. Chris Brooks of the Defence, Civil Institute of Environmental Medicine feels that motion sickness is another problem that would be encountered if this seating arrangement was utilized.

  A detailed account of the findings will be presented along with conclusions when the final phase of factors is complete.

3.2.6 **Factors Phase 5 Lateral Seating** (Cont.)



3.2.6 Factors Phase 5 Lateral Seating (Cont.)



Position 1 : Across from exit with window in
Position 2 : 4 seats away with window out
Position 3 : 4 seats away with window out

3.3 RESTRAINT SYSTEMS:

3.3.1 Related Accidents:

Vancouver Island Helicopters
Bell 204B (Helicopter) C-GRVW
Taleomey River, British Columbia
4 July, 1985

Report Number:	85-P50023 (Accident)
Information Source:	Field Investigation
Local Time:	1040 PDT
Operation:	Specialty Aerial Control
Damage:	Substantial
Pilot Licence:	Commercial Rotorcraft

Pilot Hours:	All Types	On Type
Total	4,280	470
Last 90 Days	202	165

Injuries:	Fatal	Serious	Minor
Crew	-	-	1
Passengers	-	-	-

Summary Report:

The pilot of the helicopter which was equipped with a monsoon bucket had been scooping water from a fast flowing river for about three and one-half (3 1/2) hours and was dropping it on a nearby forest fire. As the bucket was being filled, the current carried it under the helicopter and attempted to sweep the bucket downstream. In an attempt to hold the bucket against the current, the pilot applied power to the helicopter. The tail rotor struck the water, and the helicopter rotated violently into the water. During the crash, the pilot was thrown against the side of the cockpit. The helmet he was wearing was cracked from the force of the impact. The pilot's shoulder harness was not worn.

3.3.1 Related Accidents (Cont.)

During previous operations, the pilot had been able to judge the speed of the current and had picked up the bucket just as it was full and passed beneath the helicopter. On this attempt, the bucket was swept out in front of the helicopter and began to pull on the hoist line.

Instead of moving ahead to keep the bucket perpendicular to the helicopter, the pilot attempted to lift the bucket. He felt a juddering in his controls, which he thought was caused by pulling the bucket across the rocks on the river bottom.

In actual fact, it was the tail rotor blades striking the water. When the tail rotor dug in and broke the tail rotor drives, the helicopter immediately rotated to the right and crashed.

The fact that the pilot's head struck the side of the cockpit with such force as to break his helmet indicates that he might have suffered serious injury without the protection of the helmet. The shoulder harness was not used because the pilot felt he would not be able to observe the slung load adequately.

Findings:

Cause Related:

1. The pilot attempted to lift the bucket against a strong current with the helicopter not centered over the load and he allowed the tail rotor to strike the water.

Other:

1. The pilot might have suffered a severe head injury had he not been wearing a helmet.

2. The pilot's shoulder harness was not in use.

3.3.1 Related Accidents (Cont.)

Associated Helicopters Ltd.
Bell 47 J-2 (Helicopter) C-FOGA
Pedley, Alberta
01 August 1984

Report Number:	84-W40051 (Accident)
Information Source:	Field Investigation
Local Time:	1105 MDT
Operation:	Charter
Damage:	Substantial
Pilot Licence:	Commercial Rotorcraft

Pilot Hours:	All Types	On Type
Total	18,561	14,273
Last 90 Days	125	125

Injuries:	Fatal	Serious	Minor/None
Crew	-	1	1
Passengers	-	-	-

Summary Report:

The helicopter, which was on a pipeline patrol, was cruising at sixty (60) knots, approximately 200 feet above ground level, when the engine (Lycoming TVO-435) lost all power. The pilot made an autorotative landing on a railroad right-of-way, and the aircraft landed heavily on sloping terrain. The main rotor blade severed the tail boom and struck the railroad embarkment.

The helicopter was equipped with a shoulder harness in the pilot position, but the harness was not being used by the pilot at the time of the accident. Neither crew member was wearing any head protection. The pilot suffered severe head injuries, and the crewman suffered minor injuries.

3.3.1 **Related Accidents** (Cont.)

The investigation determined that the loss of engine power was due to fuel exhaustion. Prior to the flight, the helicopter was not refueled. A change of routine after the previous flight had led both crew members to believe that the other was responsible for refuelling, and neither one checked the fuel on the morning of the accident flight. As well, neither crew member recalled looking at the fuel gauge prior to or during the flight; the gauge was determined to be serviceable.

The helicopter was being operated at a speed and altitude that should have allowed a safe auto-rotative landing; however, it landed heavily enough to cause severe rotor blade flexing and structural damage.

3.3.2 **Developments:**

The Safety Programs Branch of the Canadian Aviation Safety Board's "Study of the influence of Shoulder Harnesses in Aviation Safety"[11], examined in detail information in the CASB data base from 5,294 reported accidents involving Canadian registered small aircraft over the 10 year period from 1976 to 1985. Some 3,032 of these reports had information relating to the installation of personal restraint systems in accident aircraft and the use of belts or harnesses by the occupant of the pilot's position. The study only examined information related to the pilot's position because the number of reports with similar data on the co-pilot's position was considerably smaller and because there was no consistent record of this type of information for passengers sitting behind the pilots' seats. It was found that there had been a gradual increase in both the percentage of accident aircraft with shoulder harnesses installed and the percentage of pilots who use the harnesses when they are available. Table 4 illustrates these increases. It must be noted that the study sample is of accident

3.3.2 **Developments** (Cont.)

aircraft only; however, there is no evidence to suggest that pilots who are involved in accidents are any more or less liable to install or use shoulder harnesses than those who are not. Also, though the sample represents only slightly over one percent (1%) each year of the total number of registered small aircraft in Canada, in total, it is about twelve percent (12%), and there are not wide fluctuations in the year-to-year data. Thus, the study sample is considered to be reasonably representative of shoulder-harness installation and usage generally.

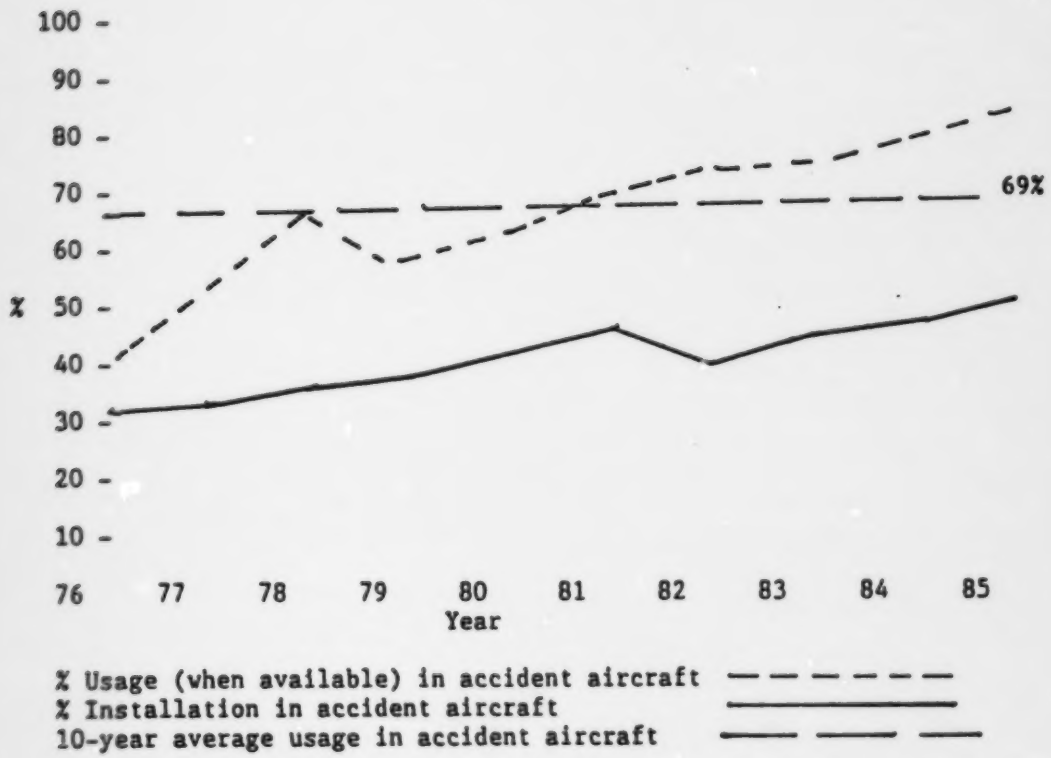
11 Study of the Influence of Shoulder Harnesses in Aviation Safety, Canadian Aviation Safety Board, 1987

3.3.2 **Developments** (Cont.)

Table 3 - Shoulder Harness Installation & Usage Rate

In Accident Aircraft

1976 - 85 Pilot Position



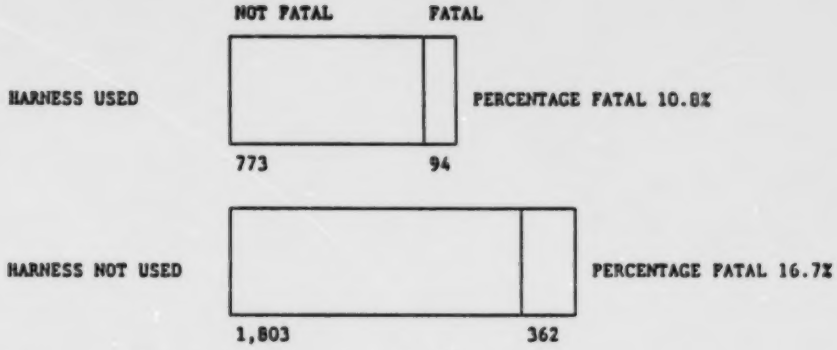
In comparison of accident pilots who wore shoulder harnesses and those who did not, it was found that 94 of the 867 pilots who used shoulder harnesses died; ie., a fatality rate of 10.8 per cent. Of those who did not use shoulder harnesses, 362 out of 2,165 died; ie., a fatality rate of 16.7 per cent. This is shown graphically at Table 4.

3.3.2 **Developments** (Cont.)

Table 4 - Comparison of Fatalities

- Harness Used/Not Used

1976 - 85 Pilot Position



United States Accident Data

The accident information retained by the CASB is not conducive to evaluating the effects of shoulder harnesses in the reduction of injuries. The definition of injury categories is quite broad, and the accident files rarely contain information on injuries sufficiently detailed to assess the effects of wearing a shoulder harness in an accident. Two (2) recent studies conducted in the United States, however, carried out detailed assessments of the injuries sustained by individual accident victims and projected the benefits which could be expected if shoulder harnesses were worn.

The first of these studies, titled The National Transportation Safety Board General Aviation Crashworthiness Project, was conducted to provide information to support recommended changes in crashworthiness design standards for seating and restraint systems in general aviation aircraft. A methodology for calculating impact severity was developed, and each of the 1,268 victims of 535 selected aircraft accidents were evaluated separately. The study determined that 1,111 of the 1,268 victims would have benefited from the protection which shoulder harnesses afford. The circumstances of 800 fatalities were evaluated, and it was estimated that 163, or 20 percent would have survived had they been wearing shoulder harnesses. Furthermore, the

study concluded that 201 of the 229 (88 percent) seriously injured persons who could be evaluated would likely have received less severe head or upper body injuries, only minor injuries, or no injuries at all had shoulder harnesses been worn.

Study two was conducted by the Civil Aeromedical Institute (CAMI) of the Federal Aviation Administration (FAA) on forty-seven (47) survivable or partially survivable accidents. It focused on the injuries of the occupants in relation to the severity of the impact, the performance of restraint systems, and cabins survivability. The accidents selected were reviewed by crash injury investigators who, based on recorded data, made judgments regarding the effectiveness of crashworthy systems. Of the 136 persons involved in the accidents, there were forty-seven (47) pilots, forty (40) occupants of the co-pilot's seat, and forty-nine (49) additional passengers. It was concluded that forty-three (43) pilots, thirty-six (36) co-pilots, and forty-two (42) passengers would have benefited from the wearing of a shoulder harness, an average of abut 90 percent. The study also concluded that, while crash forces are essentially equal in both front seats, there is a reduction of impact forces towards the rear of the aircraft because the airframe absorbs energy as it crushes.

In "Cause Factor: Human"[12], A Treatise on Rotary Wing Human Factors, details some basic requirements for restraint systems as follows:

Statistics from civilian helicopter accidents indicate that restraint system failure is a frequent cause of injury and fatality.

This is truly unfortunate because body restraint is relatively easy to establish and can mean the difference between life and death. To verify this, consider the frequency of fatal head injuries or the fact that evacuation from a burning or sinking aircraft is obviously enhanced if no prior injury or debilitation has occurred.

12 Cause Factor: Human, A Treatise on Rotary Wing Human Factors, Skjenna, O.W., 1981

3.3.2 **Developments** (Cont.)

According to the Crash Survival Design Guide, restraint harnesses for personnel and cargo should provide the restraint necessary to prevent injuries to all aircraft occupants in crash conditions approaching the upper limits of survivability. Numerous methods of restraining the human body have been proposed, and while some of these have been exceptionally good, some have left much to be desired. There are certain qualities, however, that a harness should possess if it is to be used routinely:

1. The harness should be comfortable and light in weight.

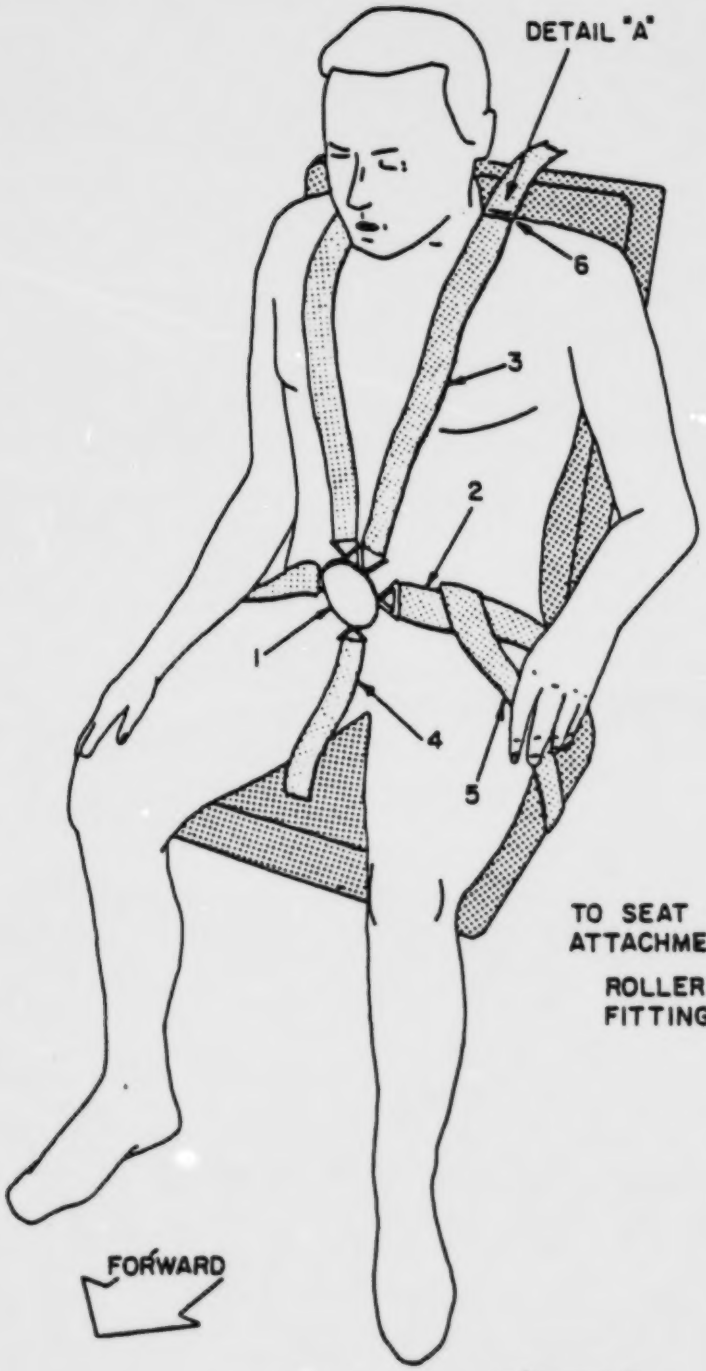
2. The harness should be easy for the occupant to put on and take off.

3. The harness should contain a single point release system, easy to operate with one (either) hand since a debilitated person might have difficulty releasing more than one buckle with a specific hand. It should also be protected from inadvertent release.

4. The harness should provide freedom of movement to operate the controls of the aircraft. This requirement often necessitates the use of an inertia reel in conjunction with the shoulder harness.

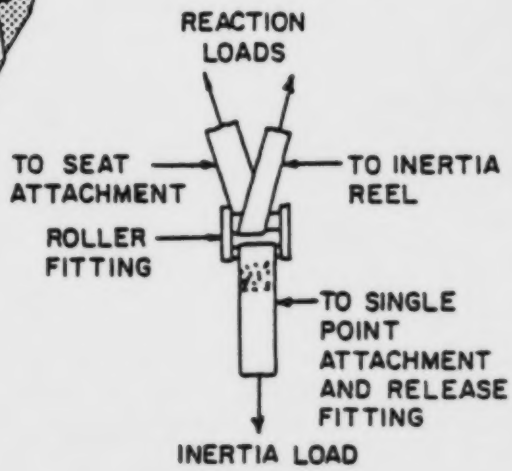
5. The harness should provide sufficient restraint in all directions to prevent injury due to decelerative forces in a potentially survivable crash.

The actual anchorage point for the lap belt can be located either on the seat bucket itself or on the basic airframe structure. If located on the airframe, consideration must be given to the movement of the seat when load limiting devices are used in order that the lap restraint remains effective. In this situation, however, the belt strength properties must be adequate to restrain the motion of the seat, as well as the occupant.



ITEM IDENTITY

1. SINGLE-POINT ATTACHMENT AND RELEASE FITTING
2. LAP BELT
3. SHOULDER STRAP
4. TIE-DOWN STRAP
5. SIDE STRAP
6. REFLECTED SHOULDER STRAP



DETAIL "A"

Figure 5

3.3.2 **Developments** (Cont.)

Restraint Anchorage

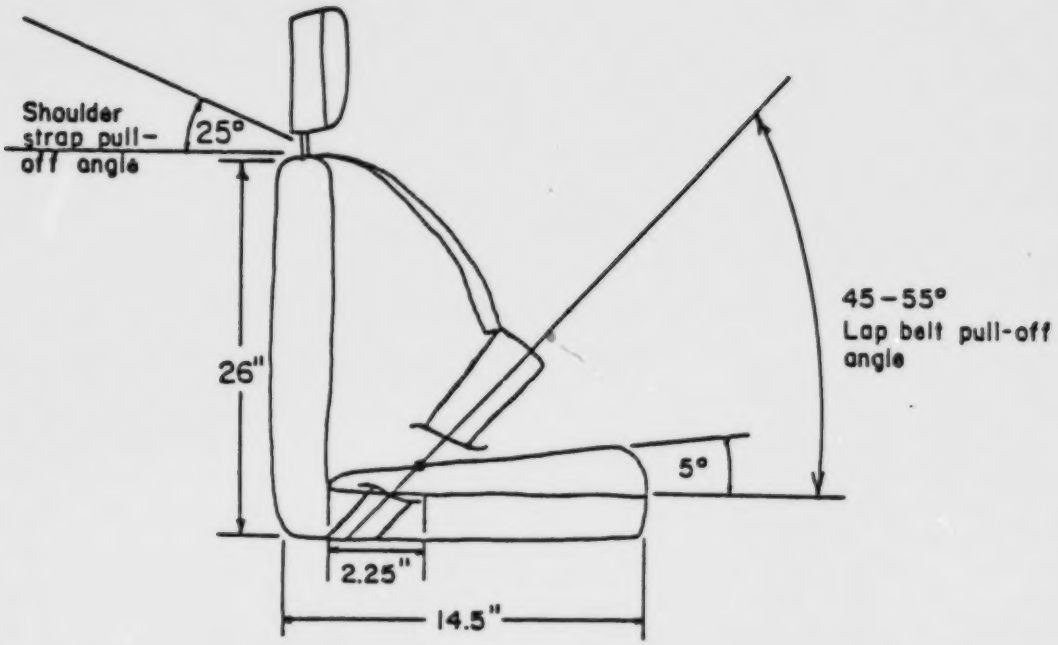


Figure 6

The lap belt should be anchored so that it provides optimum restraint for the lower torso when subjected to longitudinal decelerations. Figure 6 shows the optimum lap belt angle which will hold the belt on the iliac crests and prevent submarining during the crash deceleration. A belt tie-down strap or crotch strap attached to the centre of the lap belt will prevent upward belt movement which causes the belt to be pulled off the iliac crest and into the abdomen resulting in injury to abdominal viscera. Figure 5 illustrates an ideal system which meets all of the criteria.

3.3.2 **Developments** (Cont.)

An inertia reel installed in the restraint system provides freedom of movement and improves comfort while allowing for automatically locking the shoulder harness during an abrupt deceleration. The freedom of movement is obtained by spring loading the reel cable or webbing, which allows extension without apparent restraint. The United States Military uses two types of reels - the impact sensitive type and the rate of extension type. The older impact sensitive type takes a two (2) to three (3) G impact on the inertia reel housing itself to lock automatically. Normal flight loads will not activate this reel. The rate of extension type reel operation depends on the rate at which the harness is pulled out, a function of the direction. This system can be checked at any time by giving a jerk to the shoulder harness itself. The United States Military specifications require that both reel types lock automatically before the occupant travels more than half an inch during emergency deceleration. Accident statistics indicate that rotary-winged aircraft frequently impact on their sides or impact vertically with little longitudinal deceleration. It is, therefore, recommended that all rotary-winged craft should incorporate the rate of extension type reel.

Various materials have been tested for webbing load capabilities and elongation. It has been recommended that materials with minimum elastic stretching be used to reduce the effects of dynamic overshoot where rebounding of the material may increase the final G loading on the occupant. As examples of materials tested, dacron will elongate by approximately thirteen (13) per cent, whereas nylon will elongate by twenty-eight (28) percent. The flammability of the material should also be considered.

The ideal width for a lap belt is 2 1/4 inches, with a thickness of at least 1/10th of an inch. The shoulder belt, although it can be constructed of a thinner material, should have a two inch width.

3.3.2 **Developments** (Cont.)

Several points of advice which will improve the occupant's chance of surviving an accident are:

1. Use the restraints.

2. The restraints should have a convenient locking device.

3. Thin webbing should be replaced on shoulder straps.

4. Excessive widths for shoulder strap guides should be eliminated (the shoulder strap guide width should be no greater than three (3) inches).

5. Brief all passengers on the use of restraint systems.

3.3.3 **Industry, Academic & Regulatory Recommendations:**

AVIATION SAFETY RECOMMENDATIONS

"Study of the influence of Shoulder Harnesses in Aviation Safety"[13].

Commercially Operated Aircraft

The Department of Transport require the installation of shoulder harnesses, where practicable, in the flight crew seats of all small commercial aircraft, regardless of their date of manufacture. (CASB 87-58)

Privately Owned Aircraft

The Department of Transport institute a comprehensive program to promote the benefits of using shoulder harnesses and encourage the installation of shoulder harnesses in privately owned small aircraft. (CASB 87-59)

13 Study of the Influence of Shoulder Harnesses in Aviation Safety, Canadian Aviation Safety Board, 1987

3.3.3 **Industry, Academic & Regulatory Recommendations** (Cont.)

Mixed Freight/Passenger Flights

Authorization Guidelines

The Department of Transport amend procedures for authorizing the carriage of persons and cargo to include the requirement for the applicant to submit, for departmental approval, guidelines or instructions that will be available to company personnel for the restraint of cargo (CASB 86-24); and

Criteria Compliance

The Department of Transport require that all companies approved for the carriage of persons and cargo meet the criteria proposed in CASB 86-24. (CASB 86-25)

3.3.4 **Conclusions:**

Clearly it has been demonstrated that the use of shoulder restraint harnesses greatly decreases fatality and degree of injury in helicopter crashes.

Research and developments in this area have been substantial and it would appear to be one of the easiest, cheapest and most effective means of decreasing injuries in a survivable helicopter crash.

Traditionally, there have been five types of crash positions advocated for passengers in fixed-wing aircraft wearing a lap strap. These positions have been transferred directly and adopted in the helicopter passenger scenario with little consideration for the fact that the majority of impacts have strong vertical force components with a high chance of contact injuries.

3.3.4 **Conclusions** (Cont.)

No consideration has been given to the profound disorientation effects of sudden immersion and inversion and the effects of inrushing water. The only method to enhance escape is to adopt a crash position in which one hand always grips a part of the seat. This is called the manual physical reference point. Only with the reference point will it be possible for the survivor to form a mental image of which way to proceed to an escape hatch after the accident. There is no doubt by stabilizing the survivor in the seat utilizing a 5-point harness you will minimize disorientation during and immediately post-crash, particularly during an accident with smoke and/or fire or as mentioned before, with sudden inrushing water or darkness in sinking helicopters.

The occupant must be stabilized in the seat during the actual ditching procedure to prevent injuries and once the inrushing water arrives, he must be held securely in the seat to prevent disorientation.

NOTE: Survival Systems has observed that not one entanglement has taken place during thousands of dunker sequences utilizing the military 4-point harness system.

3.3.5 **Equipment Availability:**

Many types of harness restraint systems are readily available to suit most helicopter types and seating configurations. Individual helicopter manufacturers can suggest the most suitable harness restraint systems for their models.

The 4-point harness system is available for retro-fit on the S-76 and the Bell 212.

3.3.5 **Equipment Availability** (Cont.)

The seats on the Super Puma and S61 would have to be modified to accommodate a 4-point harness system.

Source: - Aero-Seats & Systems Inc.
Dallas, Texas

Cost: - $165 US per unit.

3.4 FUEL AND FUEL SYSTEMS:

3.4.1 Related Accidents:

Terr-Air Rotary Ltd.
Sikorsky S58J C-GMMR
Indian Arm, British Columbia
16 February 1984

Report Number:	84-P4000
Local Time:	1420 PST
Operation:	Charter
Damage:	Substantial
Pilot Licence:	Commercial Rotorcraft

Pilot Hours:	All Types	On Type
Total	14,000	500
Last 90 Days	30	30

Injuries:	Fatal	Serious	Minor/None
Crew	1	-	-
Passengers	1	-	-

Summary Report:

The helicopter was being used to transport logs from a logging area to a beach. A log, estimated at 4000 pounds, was attached to the line and lifted in the normal manner, then the aircraft moved into forward flight. A witness reported that at about 200 feet, the engine stopped suddenly. After a short delay, the load was dropped and the helicopter appeared to be under control as it followed a rugged creek bed leading to the beach. Approximately twenty-two (22) seconds before impact, the first of five (5) violent flaring maneuvers was observed. The main rotor struck trees and the aircraft, in a nose high attitude, hit rocky ground about 200 yards from the beach. **A severe fuel fed fire broke out immediately and the main portions of the helicopter were consumed.**

3.4.1 **Related Accidents** (Cont.)

The transmission and many of the engine components were melted, therefore, the cause of the power lose could not be determined. A sample taken from the fuelling source was analyzed and found to meet standards. Although examination of maintenance records revealed no discrepancies, there is evidence that the pilot, who was not a licenced aircraft maintenance engineer, performed maintenance on the engines and fuel systems. The engine had flown only twenty-nine (29) hours since installation.

The pilot flew from the left seat when employed in this type of operation, a position which allowed him to lean over the collective control while observing the hookup procedure. The aircraft had been modified to allow manual load jettisoning from the left seat. The manual release could be used if the electrical release mechanism failed. Any evidence which may have explained the delayed load release was also lost in the fire.

Bell Helicopter
C-FYJP
Near Alpine Base 3 W, British Columbia
9 October 1981

Report:	81-P10106
Local Time:	1400
Operation:	Specialty Training
Damage:	Substantial
Pilot Licence:	Commercial Helicopter

Pilot Hours:	All Types	On Type
Total	7,240	250
Last 90 days	150	60

Injuries:	Fatal	Serious	Minor/None
Crew	-	2	-
Passengers	-	2	-

3.4.1 **Related Accidents** (Cont.)

Summary Report: The helicopter, with two (2) pilots onboard, had just turned downwind on the first circuit of a mountain training exercise. The second pilot was to follow through on the controls while the other flew the circuit.

Suddenly, the helicopter started to spin left. The tail rotor pedals proved ineffective and as collective was lowered, the spinning increased in intensity. All efforts to stop the movement were unsuccessful. **The helicopter fell 500 feet on a tree covered mountainside and was destroyed by fire.**

As a result of the fire, no physical evidence was found which would have caused the anti-torque system to go to ninety (90) degrees full left pitch on the tail rotor blades.

Ground tests indicated a failure of the left control tube from the tail rotor jack-shaft to the right rudder pedal, would put the rotor blades to full left pitch.

The control tubes were destroyed. However, impact marks on the two (2) pedal assemblies indicate that both were in the full forward position at impact. it is most probable the failure occurred prior to impact and resulted in the loss of directional control.

Findings:

Cause Related:

1. Related to both types of occurrence
   Rotorcraft: Flight control system-tail rotor pitch.
   Specifically: Failure/ failed

3.4.1 **Related Accidents** (Cont.)

Lakeland Helicopters
Bell 206B (Helicopter) C-GXCX
Hummingbird Pass, Alberta
21 October 1983

Report Number:	83-W30062 (Accident)
Information Source:	Field Investigation
Local Time:	0930 MDT
Operation:	Charter
Damage:	Substantial
Pilot Licence:	Commercial Rotorcraft

Pilot Hours:	All Types	On Types
Total	2,300	2,290
Last 90 Days	200	200

Injuries:	Fatal	Serious	Minor/None
Crew	-	-	1
Passengers	-	-	3

Summary Report:

While transporting a group of geologists on a familiarization flight of oil drilling sites, the helicopter pilot entered a mountain cirque from the north. After encountering turbulence, the helicopter began to descent rapidly. In an unsuccessful attempt to arrest the descent, the engine torque limits were exceeded . Still descend-ing rapidly, the pilot turned through 180 degrees to the left, then flared the helicopter over a rough clearing on the floor of the cirque. The helicopter landed hard downwind and then rolled on to its right side. **The fuel tank was ruptured, and the contents leaked out on to the ground. The pilot attempted to shut the engine down using the fuel shut-off and the throttle control but was unsuccessful.** The engine continued to run until the fuel supply was exhausted. The rear seat passengers, who were the first to exit the helicopter, used the rear

3.4.1 **Related Accidents** (Cont.)

door. The rear door, which is hinged at the forward edge, swung forward and rested on the front door, this pre-venting the door from being opened from the inside. A rear seat passenger noticed the problem, returned to the helicopter and closed the rear door, allowing the front seat occupants to escape. The emergency locator transmitter (ELT), although selected to automatic, failed to activate and was turned on manually. Winds were observed to southerly at fifty (50) to sixty (60) knots.

The force of the air, descending over the downwind slopes because of the strong winds, exceeded the helicopter's climb capability. Signs of adverse wind conditions were not observed until the helicopter entered the cirque and the turbulence was noted.

Findings:

Cause Related:

1. The helicopter encountered a downdraft which exceeded its climb capability.

Other:

1. The rear door blocked the front door and prevented the front seat occupants from leaving the helicopter.

2. The engine could not be shut down with the use of either the fuel shut-off control or the throttle.

CH-53A

Prior to commencing evasive maneuver training, a section of H-53s attempted a rendezvous/join up. During the rendezvous turn, wingman's aircraft impacted the ground. On impact, the starboard fuel cell ruptured resulting in

3.4.1 **Related Accidents** (Cont.)

post-crash fire. After impact, pilot experienced difficulty locating his seat buckle. Once released, his personal flight gear hung up but caused no major problem during egress from the open left escape hatch. He suffered multiple body burns. The co-pilot released his seat belt and crawled out the right escape hatch or the right side of the windscreen (both were broken on impact). He also suffered multiple body burns. After impact, the crew chief found himself in the forward crew compartment with his feet caught in loose debris. He and the first Mechanic had experienced considerable entanglement with radio cords and gunner's belt straps. When another explosion occurred, his feet were freed. He attempted to rescue the trapped and unconscious first Mechanic but was unsuccessful. Since fire and smoke were engulfing the compartment, he saw a light at the rear of the aircraft and ran for it. Upon exiting, the rescue crew rolled him on the ground to extinguish his smouldering flight suit. The observer, who was sitting facing forward on the jump seat, found himself on top of the crewbox in the forward portion of the crew compartment. His helmet was tangled in his communication cord, so he removed it. He could not see anyone else, but did see a light in rear of the aircraft, so he exited there. He suffered minor abrasions and lacerations. Since the wingman had assumed on-scene rescue commander, he loaded the survivors aboard and flew them directly to the hospital helo pad for treatment.

CH-53E

Aircraft impacted ground during approach to destination landing zone with an external load. The co-pilot could not use the cockpit emergency exit because the window could not be pushed out even though the handle would move. He then exited through the broken out greenhouse in the cockpit ceiling. On impact, pilot was knocked unconscious. Ground personnel could not actuate pilot's external release handle, so ripped window from mount points in attempt to free pilot. However, rescue efforts were abandoned due to proximity

3.4.1 **Related Accidents** (Cont.)

and intensity of flames. The crew chief, first mech and thirteen (13) passengers were in the cabin section. Twelve (12) passengers were unrestrained and were not utilizing troop seats. Passenger Number thirteen (13) was seated in the crew chief's seat wearing the safety belt. The crew chief was lying on the deck using the aircrew safety belt attached to a ceiling tie-down ring. The 1st mech was either standing or seated in forward cabin wearing an aircrew safety belt attached to a ceiling-tie-down ring. When the first crash crew personnel arrived on the scene nine minutes post crash, twelve (12) occupants had been extracted from the aircraft by ground personnel. All the tail of the aircraft was engulfed in flames. Crash crew in fire suits entered the aft section and extracted one more passenger. The pilot and three passengers perished in the aircraft fire. Of the evacuated personnel, one was pronounced dead at the scene, one expired in the emergency room and eleven (11) persons survived.

3.4.2 **Developments**:

Research into preventing post-crash fires or cutting down on the severity of post-crash fires has followed three (3) main lines:

1. Modified fuels

2. Fuel inerting systems

3. Crashworthy fuel containment systems

"Cause Factor: Human" provides this overview:

Various types of modified fuels have been tried. The main principle in modifying a fuel to improve the chances of preventing a post-crash fire is to increase its viscosity so that it will not be spilled and flow around the crash site as a liquid would. However, by increasing the viscosity there are several disadvantages. Obviously to be used as a fuel, high viscosity material must be reconverted to a fluid state. In addition,

14 Cause Factor: Human, A Treatise on Rotary Wing Human Factors, Skjenna, O.W., 1981

3.4.2 **Developments** (Cont.)

studies have shown that the more viscous fuel tends to be thrown a longer distance on impact and, additionally, tends to cling to surfaces much like napalm does.

The rationale behind fuel inerting systems is elimination of oxygen, which is required for combustion, from the areas surrounding the combustible materials. Therefore such designs as nitrogen inerting systems, where nitrogen is released in the area, have been tried. Although these systems work well in a laboratory environment, in reality at a crash site there is often wind and other factors which displace the inerting gas and a fire could then result as parts may remain hot enough to ignite flammables for as long as twenty (20) minutes, particularly in the case of turbine engines.

The most promising system at present is the crashworthy fuel system whereby the fuel is contained and not allowed to spill in the first place. Perhaps a combination of these systems would provide a further margin of safety in post-crash fires. That the crashworthy fuel system is effective is illustrated by the vast reduction of post-crash fires in United States Army UH 1 Huey helicopters. In some 2,000 United States Army Huey accidents, both in combat zones and in other operations, there have only been about seven (7) post-crash fires, none of these resulting in injury to the occupants.

The ideal fuel system is one which completely contains its flammable fluids both during and after the accident. To accomplish this it is necessary that all components of the system, including fuel tanks and fittings, flammable fluid lines, fuel transfer system components, and vent systems, be properly designed with crashworthiness in mind.

The location of a flammable fuel-carrying tank in an aircraft is of considerable importance in minimizing the post-crash hazard. The location must be considered with respect to occupants, ignition sources, and probable impact areas. Greater distance between occupants and the fuel supply tends to

3.4.2 **Developments** (Cont.)

increase the escape time because it reduces the likelihood of fuel entering the occupant's area. Although it is not always feasible to keep the fuel away from a probable ignition source, one important consideration is to locate tanks away from areas of maximal impact damage such as around landing gears, etc. Location of fuel tanks under the helicopter floor poses a serious threat because of the propensity towards accidents in near level flight altitudes at high sink speeds. As much aircraft structure as possible should be allowed to crush before the tanks themselves are exposed to direct contact with obstructions. In addition, expansion areas around the tank should be provided into which the tank and its contents may displace.

As far as tank shape is concerned, a cylindrical or rectangular shape appears to be the best choice as these shapes can displace easily without snagging. The tank should be constructed of the self-sealing, puncture resistant materials used in many military aircraft.

Failure of the fuel cells is often caused by ripping out of fuel cell fittings, such as fillers and crossover fittings, allowing a tear in the tank wall to initiate. Attachments that are normally used to support the fuel cell in the aircraft, and attachment of the various tank components, such as the filler neck and the boost pump, must be designed in such a way that breakaway occurs under high loadings. A self-sealing valve should be employed in each of the fittings.

Damage to fluid lines frequently causes spillage in aircraft accidents. These are usually cut by surrounding structure or worn through by abrading against rough surfaces. The use of flexible hose, armored with a steel braided harness, is strongly suggested in areas where this is a threat. In addition, the routing of hoses should be carefully considered during the design stage. Fuel lines should be routed along the heavier structural members and away from sources of ignition such as electrical wiring. Another important item in the fuel transfer system is

3.4.2 **Developments** (Cont.)

the boost pump, which plays a major role in the initiation of the crash fire sequence. The majority of boost pumps in use today are installed in the fuel tank and are rigidly bolted to the tank and to the aircraft structure. Crash damage to the pump can cause fuel spillage and also supply electrical sparks for ignition of the fuel. Air driven boost pumps and engine mounted suction type boost pumps are alternate solutions that are much less hazardous. If design requirements dictate that a boost pump be installed in the fuel tank it would be better to use an air driven pump. The pump should be bolted only to the fuel cell unless a frangible attachment is used.

In addition to providing for improved containment of fuel, some control of ignition sources should be considered when designing helicopters. As early as possible during the crash sequence the fuel, oil and hydraulic lines should be closed off at the engine firewall and the fuel should also be cut off as close as possible to the point of induction into the engine.

The electrical system in an aircraft is a potential crash fire ignition source because it is extensively distributed throughout the aircraft and because of the large amount of energy present, compared with the small amount actually required to produce fire ignition under ideal conditions. For example, the common incandescent filament in a landing light is hot enough to ignite fuel 0.75 - 1.50 seconds after the bulb breakage. The ignition potential of the aircraft's electrical system may be reduced by modification of the electrical system to provide for removing from the electrical circuits all electrical generation or storage sources before, or during the early phases of the crash sequence, and by controlling component location in the environment.

Additional protection can be provided by installation of fuel baffles, fire curtains, drip fences, and fuel flow diverters.

3.4.3 Industry, Academic & Regulatory Recommendations:

The "CAA Harp Report"[15] stated that it supported without qualification proposals to ensure that fuel tanks are better protected (by improved linings) against rupture on crashing, and that fuel piping systems should have self-sealing couplings to prevent pipe leakage.

The report also recommended that immediate steps should be taken to require better standards of crashworthiness of fuel tanks and fuel systems.

We must add that in parallel with structural improvements is the need to ensure that exits are adequate and themselves 'crashworthy'.

3.4.4 Conclusions:

Major post crash fires are limited to fuel tank ruptures and leaks. Post crash fires present a serious threat to the escape of surviving occupants and rescue efforts. It has been demonstrated that crashworthy fuel systems can effectively decrease post crash fires thus providing a much greater likelihood of surviving occupants escaping the accident and decreasing injury.

3.4.5 Equipment Availability:

Crashworthy fuel systems are available as an option or retrofit on most helicopters. It would appear that there is a slight weight and capacity penalty with such an option. For specific details, the helicopter manufacturer must know the aircraft model, role and configuration.

15 Review of Helicopter Airworthiness, CAA Harp Report, 1984

3.5 OVERWATER OPERATIONAL SYSTEMS:

3.5.1 Related Accidents:

Okanagan Helicopter Ltd.
Sikorsky S61 (Helicopter) C-GOKZ
Halifax Int'l Airport, 40 mi.'s
20 March 1985

On 20 March 1985, an Okanagan helicopters Ltd., Sikorsky S61-N helicopter, C-COKZ, conducted a charter visual flight rules (VFR) flight from Halifax International Airport to the offshore oil rig, SEDCO 709 located at lat 43 degrees 34' North, long 60 degrees 43' West. The helicopter departed SEDCO 709 at 0938 Atlantic daylight time (ADT) on a 143-mile return flight to Halifax International Airport. On board were two (2) pilots and fifteen (15) passengers.

After take-off, the helicopter climbed to a cruising altitude of 700 feet above sea level (ASL). At about 1030 and about 20 miles offshore, the master caution light and the transmission main gearbox (MGB) oil pressure light illuminated, and the indicated torque for both engines dropped to zero. The pilot, observing that the oil pressure was about fifty (50) pounds per square inch (psi) and dropping steadily, had the emergency lubrication pump switched to the override position. At about the same time, one of the passengers noticed oil leaking down the left side of the helicopter. The co-pilot transmitted a MAYDAY on high frequency (HF) radio, and the passengers were alerted to the possibility of a ditching. The pilot descended to 100 feet, reduced the airspeed to 100 knots, and turned the helicopter towards the nearest land.

About five (5) minutes after the first light indication, the MGB oil pressure indicated zero, and almost immediately the flight crew heard a loud noise coming from the vicinity of the MGB. The co-pilot advised the company flight following of the situation on HF, and the pilot turned into wind and ditched the helicopter. Once on the water, the pilot maintained the stability by continuing to fly the helicopter. The co-pilot, after

3.5.1 **Related Accidents** (Cont.)

jettisoning his window, attached the sea anchor to the external anchor line and deployed it. To enhance stability, the landing gear was lowered. The pilot jettisoned his window, and a second MAYDAY was transmitted on HF. The co-pilot then unstrapped himself and moved aft to the cabin to assist the passengers.

The co-pilot opened the forward personnel door and deployed the number 1 (forward) liferaft. While the rotor was still turning, the co-pilot started to move the passengers into this liferaft. At the same time, the pilot proceeded to shut the helicopter down. The time from ditching to shutdown was about three (3) to five (5) minutes.

Fourteen (14) passengers were boarded in the number 1 liferaft, and the co-pilot passed the Rescue 99 emergency locator transmitter (ELT) to one of the passengers. When the pilot moved into the cabin, he removed the airframe-mounted ELT, while the co-pilot jettisoned the left rear emergency exit and deployed the number 2 (rear) life-raft. The pilot threw the ELT to the passengers in the number 1 life-raft, and the raft was released. The forward door was then closed, and a final check of the cockpit was made. The pilot then moved to the rear of the aircraft and stepped into the raft with the co-pilot and a passenger.

One hour after the helicopter was ditched, the crew and passengers were rescued by Canadian Forces helicopters.

The ditching site was located at latitude 44 degrees 38' 30" North, longitude 62 degrees 38' 25" West. The incident occurred at 1038 during the hours of daylight.

During the evacuation of the helicopter, the co-pilot boarded fourteen (14) passengers into the forward raft in an attempt to get as many of the occupants as possible away from the helicopter, as he feared the aircraft might capsize. Following a ditching, it is standard operating procedure to abandon the aircraft immediately.

3.5.1 **Related Accidents** (Cont.)

After the pilot-in-command had shut down the helicopter engines and stopped the rotor, he moved aft to the passenger cabin. Once he had passed the airframe-mounted ELT to the passengers in the liferaft, the raft was pushed away from the helicopter. As the raft moved into the outer limit of the rotor arc, the stationary rotor blades were striking the water dangerously close to the raft, and the occupants had difficulty keeping the raft from being struck by the rotor blades.

After launching the number 1 liferaft, the pilot, co-pilot, and remaining passenger inflated the number 2 liferaft beside the aircraft and stepped directly into the liferaft. The raft was then pushed away from the helicopter, and it drifted under the tail pylon. The three (3) occupants had difficulty keeping the raft clear of the stationary tail rotor blades as the helicopter was pitching and rolling in the water.

The liferafts were 12-man aircraft liferafts with an 18-man overload capacity.

Shortly after the number 1 liferaft was launched, the lower buoyancy chamber began to deflate, and water began to enter the interior of the raft through the boarding entrances. When the raft survival equipment containers were opened, the occupants were unable to find a bailing bucket or oars. In an attempt to remove the water from the interior of the raft, some of the occupants used their protective overboots as bailing buckets. By the time the rescue helicopters arrived, the occupants were sitting in about eighteen (18) inches of water.

Except for the initial difficulty they experienced clearing the helicopter, the occupants of the number 2 liferaft had no problems during the one hour they were awaiting rescue.

3.5.1 **Related Accidents** (Cont.)

A local fisherman, a member of the Canadian Coast Guard Auxiliary, recovered the liferafts and some of the survival contents. When the liferafts and their contents were examined, the following observations were made:

1. There was no reflective tape on either liferaft;

2. There were no grab lines on the inside of either liferaft;

3. The two (2) entrance areas of the liferafts are outlined with lights which are energized by a salt-water-activated battery. The batteries in both rafts were time-expired;

4. Both rafts had several large patches on the buoyancy chambers which were not stamped with the date of repair;

5. Eight D cell batteries were found wrapped in a plastic bread bag and taped closed. All the batteries showed signs of corrosion;

6. One flashlight was recovered and was not in operating condition;

7. Two (2) metal signal mirrors were recovered. The surfaces were not highly polished and were not smooth. No safety lines were attached to the mirrors, nor were there instructions or markings for their use;

8. One of two (2) flares recovered had a loose striker in the cap. The striker could have been lost when the cap was opened for use; and

9. The expiry date on a bottle of 222 pills was past due, and the pills should have been replaced during the last raft inspection.

3.5.1 **Related Accidents** (Cont.)

Notwithstanding the above observations, the liferafts met the applicable regulations. Standards for liferafts are contained in Air Navigation Orders (ANO) Series II, No. 8, Life-Saving Equipment, and the specifications to which the liferafts are manufactured are contained in Technical Standing Orders (TSO) C70. The operator's Operating Certificate (OC) was issued pursuant to ANO Series VII, No. 6, Standards and Procedures for Air Carriers Using Rotorcraft in Air Transport Operations, and the OC contained a Special Condition requiring the operator to carry liferafts.

3.5.1 Related Accidents (Cont.)

TABLE 1

HELICOPTER		DATE	TOTAL NO. ONBOARD	FATALITIES	ACCIDENT SITE	CAUSE
UNITED KINGDOM						
Bristow						
S-55T	G-AOHE	12/06/69	3		E of Gt Yarmouth	Engine Failure
S-61N	G-AZNE	04/04/73	1		NE of Aberdeen	Excessive deck movement
B206A	G-AXKE	01/08/75	1		Forties Field	Fuel shortage?
Wessex	G-ATSC	08/03/76	14		E of Bacton	Intake covers not removed?
S-61N	G-BBHN	01/10/77	3		NE of Aberdeen	Main rotor blade pocket failure?
B212	G-BIJF	12/08/81	14	1	S of Dunlin Field	Pilot disorientation
Wessex	G-ASWI	13/08/81	13	13	Off Norfolk Coast	Mechanical failure?
B212	G-BDIL	14/09/82	6	6	N Murchison Field	Night SAR - bad weather
B212	G-BARJ	24/12/83	2		Brent Field	Winch cable snagged during training
B212	G-BJJR	20/11/84	4	2	NE of Humber	Flew into sea - mechanical failure?
British Caledonian						
B214ST	G-BKFN	15/05/86	20		NE of Fraserburgh	Main rotor collective problem
British Airways International						
S-61N	G-ASNM	15/11/70	3		E of Aberdeen	Main gearbox oil leak
S-61N	G-BEID	31/07/80	15		ESE of Aberdeen	Oil cooler drive belts failure
S-61N	G-ASNL	11/03/83	17		NE of Aberdeen	Main gearbox failure
S-61N	G-BEON	16/07/83	26	20	Penzance/Scillies	Flew into sea in fog
Chinook	G-BISO	02/05/84	47		Cormorant Field	Double hydraulic failure
Chinook	G-BWFC	06/11/86	47	45	E of Sumburgh Airport	Crashed into sea - gearbox failure
S-61N	G-BEID	13/07/88	21		E of Bressay	Ditched, sank - engine failure
Management Aviation						
B0105	D-HDGB	12/07/76	4		Off E Anglia	Engine failure - ditched
Bond						
B0105	G-AZOM	24/07/84	3 or 4		Off Hunstanton	Tail rotor failure
DENMARK						
Maersk						
B212	OY-HMC	02/01/84	3	3	22nm E of Dan B	Tail rotor failure
NETHERLANDS						
KLM						
S-61N	PH-NZC	10/05/74	6	6	110nm N of Texel	Main rotor blade failure
NORWAY						
Helicopter Service						
S-61N	LN-OQA	09/07/73	17	4	SW of Stavanger	Tail rotor gearbox failure
S-61N	LN-OSZ	23/11/76	12	12	SW of Stavanger	No cause established
S-61N	LN-OQS	26/06/78	18	18	W of Bergen	Main rotor spindle failure
B212	LN-ORL	31/07/79	3		Off Stavanger	A/rotation accident
S Puma	LN-OMC	15/07/88	18		70nm Stavanger	Main rotor blade ldg edge

Brief description of 27 Civilian Helicopter Accidents into the North Sea or off the British Isles (1969 - 1987). Courtesy of Capt. (N) C. J. Brooks, Defence and Civil Institute of Environmental Medicine, Department of National Defence, with assistance from J. D. Ferguson, Rotor Wing International.

3.5.1 Related Accidents (Cont.)

TABLE 2

HELICOPTER	SANK	FLOATED	MID-AIR BREAKUP	UNKNOWN
UNITED KINGDOM				
Bristow				
S55T				?
S61N		Floated		
B206 A		Floated *		
Wessex		Floated *		
S61	Sank inverted			
B212	Sank			
Wessex			Before hitting sea	
B212	Sank			
B212		Barely		
B212	Sank			
British Caledonian				
214ST		Floated		
British Airways International				
S61N		Eventually sank		
S61N		Floated		
S61N		Eventually sank		
S61N	Sank			
Chinook		Capsized in 1 hr.		
Chinook			Crashed in pieces	
S61N	Ditched, burned, broke up & sank			
Management Aviation				
B0105				?
Bond				
B0105		Barely		
DENMARK				
Maersk				
B212	Sank			
NETHERLANDS				
KLM				
S61N	Sank			
NORWAY				
Helicopter Service				
S61N		Capsized quickly		
S61N	Sank in pieces			
S61N	Sank in pieces			
B212		Floated		
S Puma		Floated		

* Sank on salvage

A list of 27 Civilian Helicopter Accidents that ditched into the North Sea or off the coast of the coast of the British Isles (1969 - 1987) describing whether they sank or floated after ditching. Courtesy of Capt. (N) C. J. Brooks, Defence and Civil Institute of Environmental Medicine, Department of National Defence, with assistance from J. D. Ferguson, Rotor Wing International.

3.5.2 Developments:

The frequency of forced landings (and hence in over water operations, of ditching) is such that a high probability of survival of all occupants is essential. To achieve this, the helicopter must have adequate buoyancy, stability, practicable means of escape and effective liferaft and survival equipment.

Buoyancy needs to be assured in order to provide the pilot with ditching as an acceptable option, and there are strong arguments in favour of deployment of flotation bags before contact with the water. Reserve buoyancy may be desirable in the event of survivable damage. The need for stability is emphasized by the very limited practicality of escape from a capsized helicopter. The conditions on which the stability of the helicopter should be demonstrated must take account of realistic wind speeds and sea states.

Examination of sea conditions which are critical to the helicopter has shown that relatively confined sea areas cause more problems than the open ocean.

This is because wave height in itself is not as critical as wave steepness when considering the capsize of helicopters. The other critical factor is the breaking wave because it has been shown that the majority of capsizes are caused by them.

Helicopter Floatation Systems

On "An Examination of Problems Associated with the Waterbourne Behavior of Helicopter"[16], Mr. D. L. Williams gives the following over-view of the floatation problems. Helicopters are inherently unstable in water and will capsize, usually in roll but capsize in pitch can also occur.

Figure 7 shows a typical helicopter layout and the important factor is that its centre of gravity is high and the centre of buoyancy is low so that a small angular rotation of the machine in roll makes it unstable and capsize

16 An Examination of Problems Associated with the Waterbourne Behaviour of Helicopters. Williams, D.L., 1987

3.5.2 **Developments** (Cont.)

is then inevitable (figure 8). Because there is buoyancy at a relatively long distance forward and aft of the c.g. in pitch, much higher angles of rotation can be attained before capsize occurs. Nevertheless, as stated previously, it does happen.

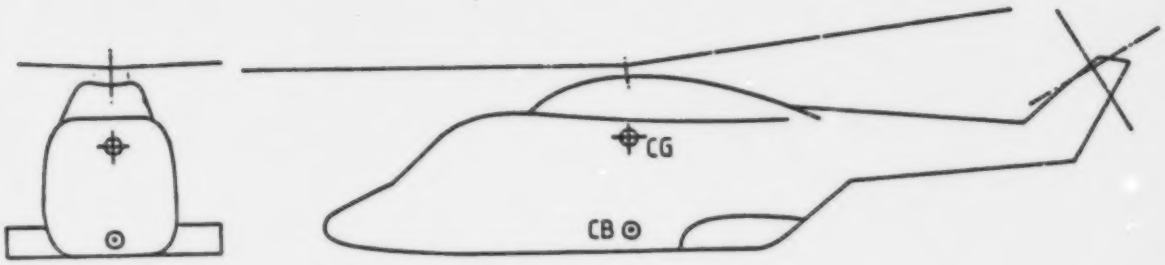


Figure 7

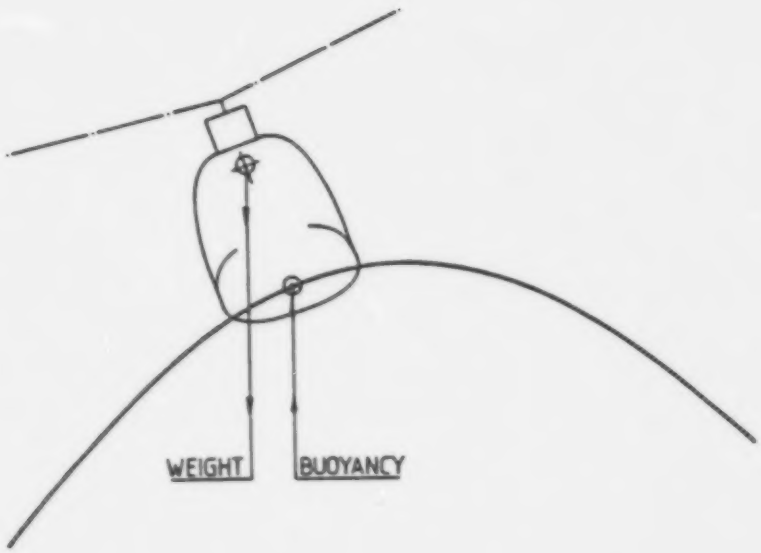


Figure 8

3.5.2 **Developments** (Cont.)

At present this situation is countered by adding pop out emergency floats to the skid undercarriages or the sides of the fuselage. These primarily improve the roll stability but by suitable distribution longitudinally they also improve the pitch characteristics. They are positioned low on the helicopter in order to keep the flotation line below the door sills, a C.A.A. requirement to avoid the occupants becoming very wet before getting into the life rafts.

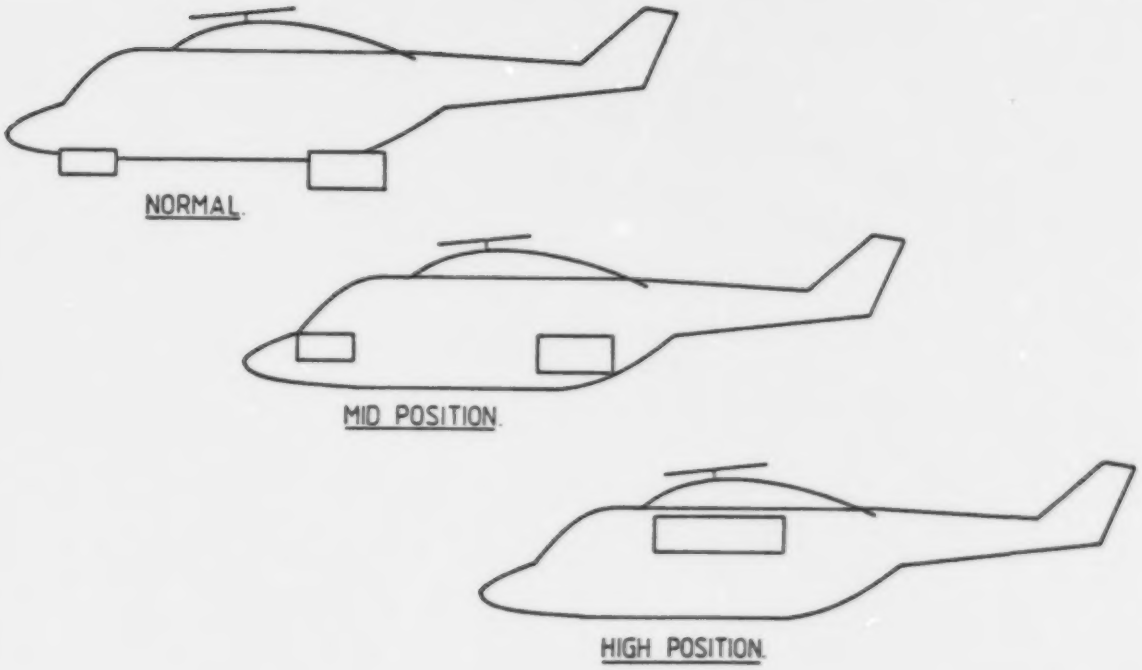


Figure 9

3.5.2 **Developments** (Cont.)

Very little can be done about the basic vertical position of the c.g. and its upward movement (ie. more de-stabilizing) as you reduce weight by consumption of fuel or carrying fewer passengers. The alternative is to raise the centre of buoyancy, such as by raising the floats. This is not easy because at mid fuselage height they could block the emergency exits. So either they are moved a small amount or a large amount to, say, the top of the fuselage (figure 9).

This latter float position has been proposed as an alternatives solution to the basic problems. That is, accept that the helicopter will capsize and position the floats so that it is kept on its side but does not invert. Obviously this makes escape more difficult in that the occupants will be lying on their sides and have to release themselves from this position and then scramble up past seats etc. to get to escape hatches on the uppermost side of the fuselages. Model tests conducted at EEL Test Facility in England have shown that in fact the helicopter lying on its side is still vulnerable to being inverted by the action of the waves.

With the floats at an intermediate vertical position the helicopter will loll over to one side or the other and in such a rolled condition it is still vulnerable to capsize. So the machine must be allowed to flood quickly to bring it to a level and lower position in the water. In so doing the occupants will become thoroughly wet but the resulting floating position will be much more stable. This latter situation is accepted in the military field and could conceivably be accepted in oil field operations because everybody wears immersion suits.

In the meantime an addition to the existing pop out floats has been devised which improves the stability of a given helicopter particularly at low weights. These are known as water pockets or scoops and are mounted on the outboard surfaces of the floats such that when the floats are deployed they fill up with

3.5.2 **Developments** (Cont.)

water (figure 10). The scoops can be retrofitted to existing floats as well as being incorporated in new designs. The weight penalty and increase in volume of the stowed float is small.

Scoop Configuration

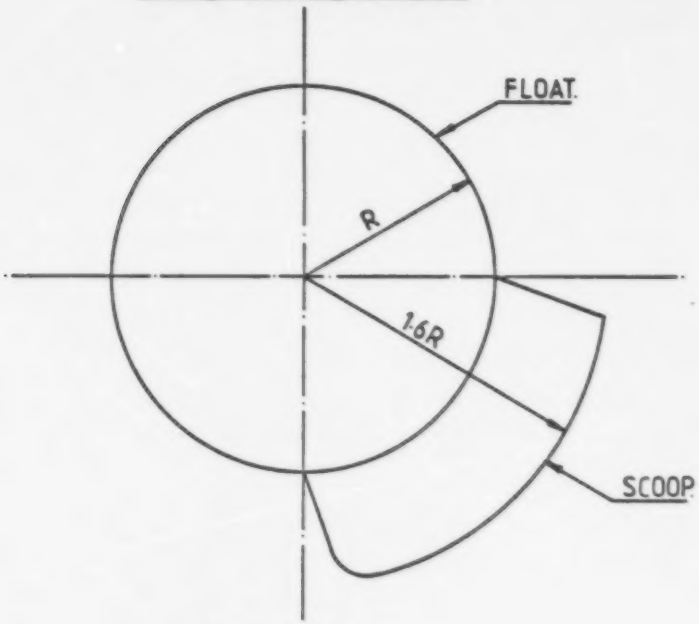


Figure 10

The scoops have been tried in model form at the EEL Test facility on several types of helicopter and have shown that roll stability is usually maintained in one sea state greater than without them. Floats have now been designed and built with scoops for one military aircraft and incorporation of scoops in a re-design of the float system for an existing civil helicopter is well advanced.

Further Update

Bristow Helicopters Limited were involved with Westland/EEL in water scoop development testing for the Bell 212.

3.5.2 **Developments** (Cont.)

They were however, forced to defer the development due to load/stress problems associated with the float attachments.

No further work is expected to take place.

Egress & Survival

Given a successful auto-rotative landing, the next problem is egress and survival. Considering the high probability of occupants getting wet due to capsize, or necessity to enter the water before entering the liferaft, immersion suits are extremely important. With the recent completion of a Canadian standard for Helicopter Passenger Transportation Immersion Suit Systems which to a great degree was initiated and supported by the Canadian Oil and Gas Industry, passengers now have excellent protection in the event of cold water immersion. The suits that now meet the Canadian Standard offer good thermal protection, mobility and virtually no leakage. Therefore, if one needs to enter the water, one can do so with reasonable confidence. Pilots may not have the same degree of protection as they are not required to wear approved suits. However, even the best helicopter immersion suits only protect a person in freezing water for hours versus days in a liferaft.

Traditionally, liferafts have been stored inside the helicopter and require manual deployment from an upright helicopter and inflated immediately beside the helicopter to facilitate dry boarding. Liferafts have been toughened with little weight increase using composite gas bottles and heavier fabrics. Recent helicopter liferaft designs have included reversible liferafts to eliminate the problem of the raft inflating upside down and use the canopy support tube with an added rubbing streak to lessen the possibility of damage to the sponson alongside the aircraft. However liferafts are still subject to puncture and fuel or oil contamination. Therefore, it is recommended to swim the liferaft away from the helicopter before inflating.

3.5.2 **Developments** (Cont.)

There is still the problem of deploying the liferaft if it is stored inside the helicopter. The minute an occupant releases his seatbelt in an upright helicopter on the water he becomes vulnerable. That is, an upright helicopter on the water has the potential to roll inverted. If an occupant is unrestrained during the capsizing, he will become disoriented, possibly injured and have difficulty egressing from the helicopter. Therefore, the time between releasing a seatbelt and exiting the aircraft should be as short as possible. Going to a stored raft, releasing its restraint belt and dragging it to the nearest large exit can be time consuming.

If the helicopter rolls inverted, the problem of exiting the helicopter with the liferaft are compounded. In fact the chances of getting the liferaft out of the helicopter are remote. Since re-entering an inverted helicopter is not recommended by the helicopter operators or manufacturers, the occupants are now faced with survival in the water.

Some modern passenger transport helicopters have as an option, externally mounted liferafts which can be either remotely deployed by the pilots or manually deployed. Other manufacturers can modify an emergency exit with a liferaft which can be either remotely deployed or manually deployed. However these systems still require the physical functioning of the jettison system.

A system similar to that employed in the marine and offshore oil industry may provide the answer. A water pressure activated hydrostatic release located on the upper section of the helicopter would not fire unless the helicopter was inverted or sunk up to the ceiling. Further should the helicopter sink a weak or break link at the helicopter end of the raft line would preclude the raft sinking with the wreck. In other, less time critical scenarios, the rafts could be deployed manually (as they are in the marine environment) taking care not to break the weak/break link and lose the raft.

3.5.3 Industry, Academic & Regulatory Recommendations:

As a result of the investigation of the Sikorsky S61 ditching of Halifax on March 20, 1985, the Canadian Aviation Safety Board recommended the following:

The Department of Transport amend Air Navigation Order Series VII, No. 6, to make provision for the wearing of immersion suits by passengers and crew on board all helicopters flying over Canada's offshore and northern waters. (CASB 86-28)

The Department of Transport ensure that all immersion suits required by CASB 86-28 meet minimum performance standards through their in-service life. (CASB 86-29)

The Department of Transport amend the Engineering and Inspection Manual to include more specific standards and controls for the inspection of life-rafts used on Canadian aircraft. (CASB 86-30) Overhaul Facility Audits The Department of Transport strengthen the audit procedures for centres approved by the Department of Transport for the overhaul of life-rafts used on Canadian aircraft. (CASB 86-31)

The Department of Transport develop a minimum standard, including inspection procedures and maintenance schedules, for the emergency equipment to be placed or attached to life-rafts as listed in Schedule II and Schedule III of ANO Series II, No. 8. (CASB 8632)

The Department of Transport increase the requirements for the carriage of signalling devices on all life-rafts carried on aircraft in order to facilitate the timely location of survivors in all weather conditions. (CASB 86-33)

The Department of Transport prescribe adequate inspection procedures and maintenance schedules to ensure the continuing serviceability of the signalling devices required above. (CASB 86-34)

3.5.4 Conclusions:

Because helicopters are inherently unstable while floating in water, emphasis must be placed on improving the stability. Inflation bag scoops should be considered as an interim measure.

Helicopter involved in overwater flight should have a method to automatically jettison the liferafts when rapidly sinking or capsizing.

Developments in liferaft design have decreased their vulnerability to puncture. These products should be considered when replacement is necessary, or when the option presents itself.

3.5.5 Equipment Availability:

Floatation bags are an option on most commercial helicopters. It would appear that scoops can be retrofitted to these bags without too much difficulty.

Externally mounted and jettisonable liferaft systems are available as an option on some modern passenger transport helicopters. There are systems available which can be retrofitted to some helicopters.

New developments in aviation liferafts have produced a raft which is less prone to puncture as well as being reversible.

Update Jettisonable Liferafts:

AS332L Super Puma:

Availability: - Immediate Delivery

Source: - Aerospatiale

Cost: - $32,000 US per unit

* See Annex A for Technical Description.

3.5.5 **Equipment Availability** (Cont.)

Sikorsky S61:

Availability: - Approximately 2 months

Source: - Metair, UK

Cost: - $80,000 US per unit

* See Annex A for Technical Description.

Bell 212:

Availability: - Immediately

Source: - Aero-Seats and Systems Inc., Dallas, Texas

Cost: - $16,000 per ship, two units per aircraft.

Description: The system allows the pilot or co-pilot to deploy either or both rafts without leaving their seat. The raft is tethered to the helicopter with a 200 lb. shear link in the 100 ft. line. The rafts can be released by the passengers in an emergency situation from inside or outside of the aircraft. There is no outside contour change to the aircraft and no seating loss for passengers.

Totral weight gain for the Bell 212 is 10 lbs.

NOTE: Same unit available for Sikorsky S76 A and B.

Cost: - $30,000 US per unit, two units per aircraft.

Weight increase is approximately 20 lbs.

3.5.6 **Factors Phase 2A, Jettisonable Liferaft Encasement:**

Survival Systems has replicated the Metair Lifehatch which is currently fitted to the S61 N helicopter. This replica was installed onto the Modular Egress Training System (METS) for evaluation.

The purpose was to determine whether it was possible for a passenger to manually jettison this escape hatch with built-in liferaft from an underwater inverted scenario.

Seating arrangements were configured in the METS simulating the S61 N.

Each seat was equipped with a standard aviation lap belt which was used in previous phases of study. Twenty-seven subjects ran through seven sequences. The first sequence was not evaluated but was used as a familiarization sequence for the subject.

The remaining six of the sequences were monitored by qualified underwater escape instructors and evaluated as to a pass or fail. A questionnaire was also included with details of any problems encountered.

There were three different seating position variations.

Each subject was given a briefing utilizing an S61 N boarding card on such items as functioning the exit release mechanism, jettisoning the exit and a crash position to be assumed.

For reasons of control, each subject was told to assume the same type of crash position.

Preliminary Observations:

- Majority of subjects were unsuccessful at escape.

3.5.6 **Factors Phase 2A,**
Jettisonable Liferaft Encasement (Cont.)

Problems:

- Difficulty in locating function handle; and

- Difficulty in functioning handle because of lack of purchase.

- Both of the accompanying plots support the result that in phase 2A, the seat position directly in front of the exit, proved to be the greatest cause of disorientation and difficulty in getting to the exit mechanism. Position 2 is initially more difficult, but after repetition it becomes easier to negotiate.

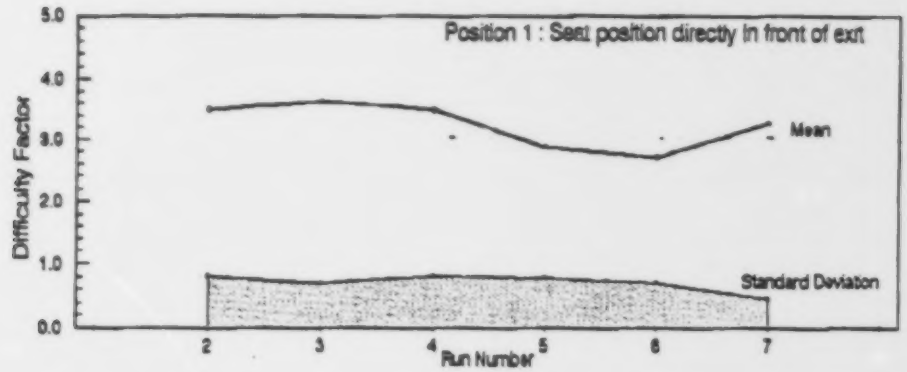
A detailed analysis will follow once the last factors phase is complete.

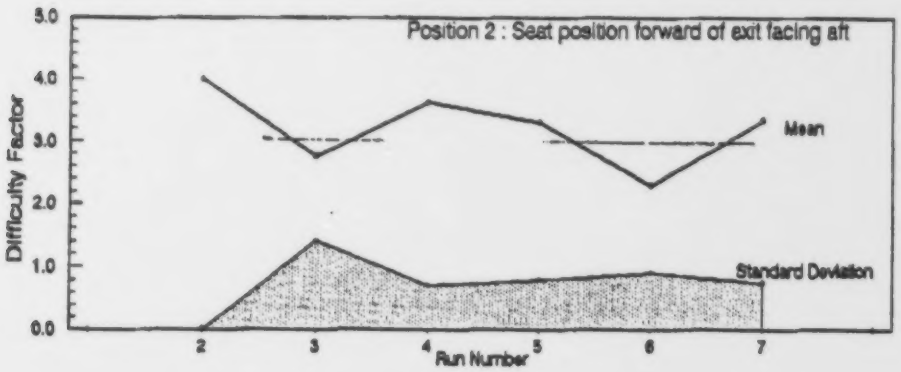
3.5.6 Factors Phase 2A,
Jettisonable Liferaft Encasement (Cont.)

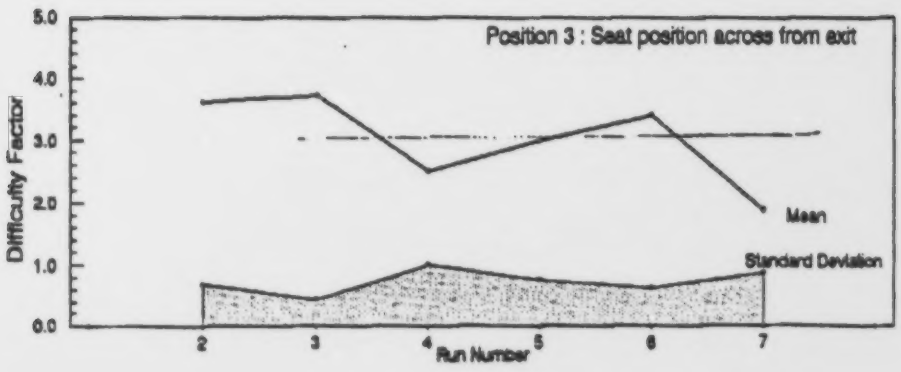
FACTORS PHASE 2A

SUBJECT'S PERCEIVED DIFFICULTY

DUE TO DISORIENTATION



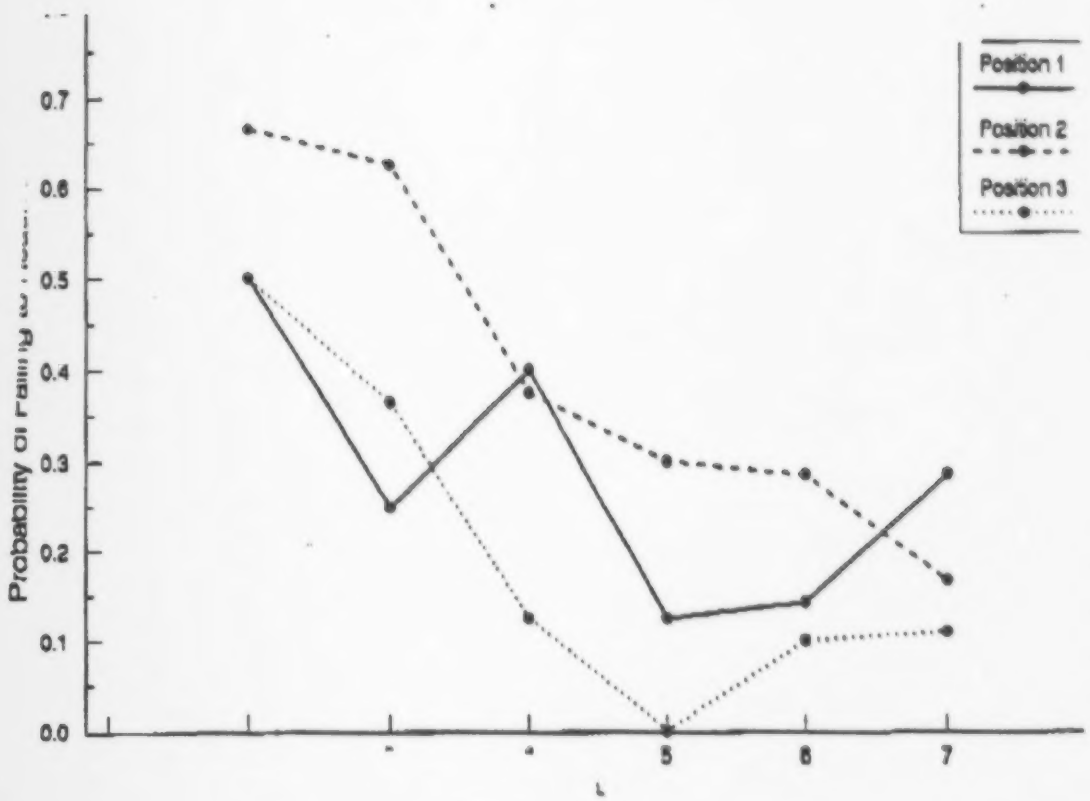




3.5.6 Factors Phase 2A,
Jettisonable Liferaft Encasement (Cont.)

FACTORS PHASE 2A

DIFFICULTY IN REACHING EXIT



3.6 WIRE WARNING SYSTEMS:

3.6.1 Related Accidents:

Trans Canada Helicopters
Bell 206 A C-GNEH
Pine House, Saskatchewan
11 August 1984

Report Number:	84-C44025 (Incident)
Local Time:	2130 CST
Operation:	Charter
Damage:	Minor
Pilot Licence:	Commercial

Pilot Hours:	All Types	On Type
Total	2,500	1,800
Last 90 Days	147	147

Injuries:	Fatal	Serious	Minor/None
Crew	-	-	1
Passengers	-	-	3

Summary Report:

The helicopter, while following a country road, struck a power line. The pilot continued his flight to destination.

A main power line ran parallel to the roads and was seen by the pilot; however, he did not see a feeder line which was strung across the road. Because the flight was operating one hour after sunset in dusky light conditions, the feeder line was difficult to see. It was also reported that fatigue was a factor in reducing the pilot's attentiveness.

There was no operational requirement to fly the aircraft at such a low altitude.

3.6.1 **Related Accidents** (Cont.)

Findings:

Cause Related:

1. The aircraft was flown at an unnecessarily low altitude.

2. The power line was not observed in the dusky light conditions.

3. The pilot's attentiveness was impaired by fatigue.

Other:
- Nil -

Huisson Aviation Limited
Bell 206L-1, C-GBZD
Marathon, Ontario 4 Miles East
9 August 1984

Report Number:	84-040053 (Accident)
Information Source:	Field Investigation
Local Time:	2000 EDT
Operation:	Charter
Damage:	Substantial
Pilot Licence:	Commercial

Pilot Hours:	All Types	On Type
Total	1,658	1,600
Last 90 Days	130	127

Injuries:	Fatal	Serious	Minor/None
Crew	-	-	1
Passenger	-	-	3

Summary Report:

The helicopter, which was not equipped with a wire cutter, returning to base when reduced visibility, fog and 200 feet ceilings were encountered. In order to maintain visual flight in rising terrain the pilot flew up a river valley.

3.6.1 **Related Accidents** (Cont.)

Suddenly, directly in front of the helicopter, a power line was observed stretching across the river. As the pilot pulled up to clear the power line, the tailboom struck the top wire. Tail rotor control was lost and the pilot autorotated straight ahead into the river. The aircraft settled into the water, and as it rolled onto its side, the main rotor blades severed the tailboom.

The poles supporting the power line were hidden by the trees on either side of the river. Although the helicopter's speed had been reduced, the power line was not seen in time to be avoided. In order to clear the power line, the pilot flared and applied collectives. This brought the tail down into contact with the top wire, bending tail boom up and causing a loss of tail rotor control. Following the autorotation, the sloping river bed allowed the helicopter to roll onto its side.

Findings:

Cause Related

1. Fog and low ceiling restricted the pilot's visibility.

2. The power line was not observed in time to avoid a wire strike.

3. The helicopter struck the top wire of the power line.

4. The helicopter was not equipped with a wire cutter.

3.6.1 **Related Accidents** (Cont.)

Other

1. The helicopter rolled over on touchdown, due to the sloping river bed.

Royal Canadian Mounted Police
Bell 206B (Helicopter) C-CDXB
Ucluelet, British Columbia 46 Miles North East
14 December 1983

Report Number:	83-P30080 (Accident)
Local Time:	1530 Pacific Daylight Time
Operation:	State
Damage:	Destroyed
Pilot Licence:	Commercial Rotorcraft

Pilot Hours:	All Types	On Type
Total	10,483	2,650
Last 90 Days	98	98

Injuries:	Fatal	Serious	Minor/None
Crew	2	-	-
Passengers	-	-	-

Summary Report:

During a patrol of a remote logging area, the helicopter's main rotor blade struck the upper cable of a two-cable system which was strung across a valley and used for logging operations. The aircraft fell and struck the ground in an inverted position, killing both occupants.

The narrow, steep-sided valley at the accident sites is oriented in an east and west direction and is situated in mountainous terrain. Two logging cables, which cross the valley, are anchored in a rock at the 800-foot level of the

3.6.1 **Related Accidents** (Cont.)

south slope and strung to a support tree at the 1800-foot level of the north slope. There is another support tree and the system is anchored to a tree at the 2,950-foot level. The elevation of the floor of the valley is about 640 feet above sea level.

The main rotor blade struck the top cable at a point 302 feet above the valley floor. The helicopter passed between the cables which at that point were about 80 feet apart, and it continued for 566 feet before hitting the ground. The cable, which was about one and one-quarter inches in diameter, severed a three and one-half-foot section of the main rotor blade tip; the resulting imbalance caused a complete loss of control.

The helicopter struck the cable at high speed while flying in a westerly direction. The accident occurred about one-half hour before sunset. The low angle of the sun would have made the cable difficult to see. The cable was not marked and it did not have other visual cues that would have made it conspicuous. In addition, the dark cable blended in with the background. The helicopter's high speed, the poor light conditions, and the absence of visual cues from the unmarked cable likely prevented the pilot from seeing and avoiding the cable. Normal practice for low-level helicopter operations is to fly at slower speeds in areas where obstructions could exist.

3.6.1 **Related Accidents** (Cont.)

A Class 1 NOTAM (Notice to Airmen) had been issued by Transport Canada when the cable was originally installed. The NOTAM incorrectly identified the name of the valley, its location, and the height of the cable. It was automatically cancelled about four months before the accident on the date that the cable was supposed to have been removed. A new NOTAM had not been issued at the time of the accident. The RCMP helicopter detachment office did not receive NOTAMs nor was it normal practice to determine through a flight service station or some other source whether significant NOTAMs were in effect prior to flight departure.

In accordance with the Air Regulations, Transport Canada assess individual structures to determine whether they constitute a hazard to air navigation and thus require marking. Transport Canada, based on the information it received, decided marking of the cable was not required and did not conduct an inspection of the site. The Transport Canada Guidelines for Assessment of Objects Affecting Navigable Airspace (TP875E) indicate that an obstruction is considered hazardous when it exceeds 500 feet above the ground and when it is within two nautical miles of a visual flight rules (VFR) air route used extensively by small aircraft. The actual maximum height of the cable above ground was about 400 feet. The information published in the NOTAM indicated that the cable was 600 feet or more above the

3.6.1 **Related Accidents** (Cont.)

valley floor. The cable is located in a valley which is less than two miles from the highway between Port Alberni and Ucluelet. The highway could be used as a VFR air route.

A wire cutter was due to be installed on the aircraft during the next major inspection. However, the system does not protect against a direct rotor blade strike, and it is not designed to cut through a cable of this size.

The following laboratory reports were completed: LP 459/83 - Airframe Wreckage, LP 12/84 - ELT Analysis, LP 18/84 - Wreckage Remnants, LP 19/84 - Warning Light Panel.

Findings:

Cause Related

1. The helicopter's high speed, the poor light conditions, and the absence of visual cues from the unmarked cable prevented the cable from being seen and avoided.

Other

1. An inspection of the site was not conducted to ascertain whether the cable should be marked.

2. The information provided in the NOTAM was incorrect.

3. The original NOTAM was cancelled without confirmation that the cable had been removed.

3.6.1 **Related Accidents** (Cont.)

4. It was not normal practice for the helicopter detachment to determine whether significant NOTAMs were in effect prior to flight departure.

3.6.2 **Developments:**

Operating in all weather conditions, by day or night, a wire warning system can improve the safety of low-flying operations by assisting the pilot in identifying this particular type of hazard.

On flight trials in various types of aircraft the system has demonstrated accuracy and reliability coupled with simplicity and effectiveness.

The detection range can be up to 1,600 meters (1 mile) depending on the sensitivity setting. Typically, detection of a power line at a range of about 500 meters would give 10 seconds warning time to the pilot of an aircraft flying at 100 knots.

Civilian applications include air ambulance, aerial application, forestry, police work, inspection of utilities (gas, hydro etc.), V.I.P. transport and many other operations.

Pilots of helicopters are now able to detect and thus avoid high-voltage overhead power lines with the help of these compact and lightweight systems. The system consists of a sensor unit and instrument mounted display and is designed for low cost installation in many civil & military rotary wing aircraft types.

3.6.3 **Industry, Academic & Regulatory Recommendations:**

Wire Warning Systems are a recent development and presently no recommendations are presented.

3.6.4 Conclusions:

For operations where low flying is required, a wire warning system may have merit given the number of reported incidents.

3.6.5 Equipment Availability:

This study was able to source one supply of a wire warning system. This information is contained in the annex.

3.7 FLIGHT DATA RECORDERS:

3.7.1 Related Accidents:

The following are two examples of recent helicopter accidents in Newfoundland. The value of a recorder on a helicopter is clearly illustrated by a comparison of the two investigations:

1. On 13 March 1985, a Bell 214 crash into the sea near Argentia. There were no survivors and no witnesses to the accident. Recorders were not installed on the helicopter, and as a result, considerable difficulty has been encountered in the determination of the cause factors.

2. On 27 April 1985, an Aerospatiale Super Puma was destroyed at St. John's after a dynamic roll-over during a hover taxi. The aircraft was equipped with a CVR although one was not required by regulation, and the CVR was instrumental in assessing the crew's response to the control problems and in determining cause factors.

3.7.2 **Developments:**

Flight data recorders have long been required in commercial passenger airplanes. Although they provide no safety enhancement for those occupants onboard, they do generally enhance flight safety. The recorder provides pertinent data in the event of an accident that assists investigators to determine the cause of the accident. This becomes very useful in determining a defect in a particular aircraft model which can prevent further such incidents or determine whether human error was involved.

In section 3.7.3 the order regarding flight data recorders refers to pressurized aeroplane as the key descriptive phrase. Helicopters are neither pressurized nor are they aeroplanes. They are aircraft and or more specifically rotor craft. Under these terms, they are not required to carry flight data recorders. In the case of the Argentia accident, it has been speculated that with a good Flight Data Recorder, as required in Britain, the accident at Edmonton of a 214 ST might not have occurred. Further legislation in this area is presently under discussion.

3.7.3 **Industry, Academic & Regulatory Recommendations:**

AIR NAVIGATION ORDER,
SERIES II, NO. 13/CRCC.-44

ORDER RESPECTING FLIGHT DATA RECORDER

Short Title

1. This Order may be cited as the Flight Data Recorder Order.

2. In this Order, cockpit voice recorder means a system of cockpit voice recording equipment that has been approved by the Minister; flight data recorder means a system of flight data recording equipment that complies with the requirements set forth in the Schedule.

3.7.3 **Industry, Academic & Regulatory Recommendations** (Cont.)

Application

3. This Order applies to turbo-prop and turbo-jet powered pressurized aeroplanes.

General

4. Subject to sections 7 and 8, no person shall operate a turbine engine powered pressurized aeroplane that:
   (a) has a maximum certified take-off weight of more than 12,500 lbs, and

   (b) is registered as a commercial aircraft under Part II of the Air Regulations, unless that aeroplane is equipped with a serviceable and functioning flight data recorder.

5. The installation, accuracy, systems correlation, survivability and retention of recorded intelligence and calibration check results of a flight data recorder shall be in accordance with requirements set out in the Engineering and Inspection Manual published under the authority of the Minister.

6. REVOKED.

7. Where a flight data recorder becomes inoperative but the cockpit voice recorder is serviceable and functioning, an aeroplane may be flown on such flights as are necessary to complete a planned itinerary to a maintenance base.

8. (a) An aeroplane in which both the flight data recorder and cockpit voice recorder are inoperative shall not commence a flight unless authorized to do so by the Minister.

   (b) Where a flight is authorized under subsection (a), the operator of the aeroplane shall make and retain a report of the circumstances relating to the authorization for a period of six months from the date of the authorization.

3.7.3 **Industry, Academic & Regulatory Recommendations** (Cont.)

SCHEDULE (s.2)

1. Each flight data recorder shall record at least the following parameters:

   (a) time;
   (b) pressure altitude;
   (c) indicated airspeed;
   (d) vertical acceleration; and
   (e) magnetic heading.

2. Where an aeroplane is designated by an air carrier for the carriage of passengers, its flight data recorder, in addition to recording the parameters set forth in item 1, shall record:

   (a) force applied to control column or control column positions;

   (b) force applied to rudder pedals or rudder pedal position;

   (c) force applied to control wheel or control wheel or control wheel position;

   (d) position of horizontal stabilizer;

   (e) out-of-trim condition;

   (f) auto-pilot on - off selection;

   (g) engine power including
      (i) engine torque,
      (ii) engine RPM, and
      (iii) fuel flow;

   (h) ambient air temperature; and

   (i) pitch attitude.

3.7.4 **Conclusions:**

Flight data recorders would enhance flight safety and contribute to accident prevention through better post-accident investigative results. Since these recorders are not presently required by regulation in helicopters, they are not likely to be installed unless requested by the client.

The Ministry of Transport are attempting to formulate regulations on Cockpit Voice Recorders and Flight Data Recorders.

The aircraft involved in this legislation will be all multi-engine offshore helicopters. It has been suggested that it will be at least 1 year minimum before this become effective.

3.7.5 **Equipment Availability:**

Numerous makes and models of flight data recorders are available with a wide price range. Consultation with regulatory authorities would assist in determining requirements and compliance with possible future regulations.

Bristow Helicopters Ltd. (BHL) Integrated Flight Data Recorder/Cockpit Voice Recorder and Health and Usage Monitoring System (HUMS)

The UK CAA have mandated the carriage of Flight Data Recorders (FDR) on all helicopters above 7,500 kg by February, 1991. Within this time scale, BHL have committed to developing and fitting an integrated system which will include the mandatory FDR/CVR requirement in one crash protected unit and will also introduce a Health and Usage Monitoring System incorporating the following features:

- Gearbox health monitoring through vibration analysis and oil debris detection;

- Rotor track and balance through 'inflight' measurement of track and vibration data and ground based diagnostics package;

3.7.5 **Equipment Availability** (Cont.)

- Full engine health monitoring;
- Flight manual exceedance recording;
- Inflight power assurance measurement; and
- Selected temperature and strain gauge measurement.

This system has been developed through a series of trials which were managed by BHL as part of a feasibility study over a three year period.

The system is adaptable for any aircraft type but is currently being integrated into the following:

- AS332L;
- S76A;
- S61N;
- B212;
- B412;
- B214ST; and
- AS365N.

The system cost will be dependent on helicopter type but will be in the region of 140,000 Pounds Sterling for the AS332L Helicopter and S61 N. This price includes the installation kit and all equipment.

4.0 CONCLUSIONS

Over the past decade, the number of aircraft accidents per 100,000 hours flown has decreased from 19.1 in 1976 to 13.5 in 1986. However, while fewer accidents occur now than a decade ago, the chance of surviving if an accident occurs has not significantly improved. However, there are presently some safety developments which can improve occupant safety.

One of the most effective safety improvements, offering the least weight and cost penalties is the installation of shoulder restraint harnesses. As discussed in Section 3.3, this greatly contributes to the reduction in the seriousness of injuries in most accident scenarios.

Crashworthy fuel systems is another improvement, particularly for overland operations, which significantly reduces thermal injury in an accident. In most cases this is not an easy retrofit item and therefore should be considered during initial acquisition of the helicopter from the manufacturers. In the case of "in-cabin" auxiliary fuel tanks, the crashworthy system may be a feasible option. Again, there is little weight penalty although the cost is greater than the restraint harness.

Overwater operations should consider externally mounted liferafts and an automatic deployment system as well as retrofitting inflation bags with scoops. Because of the oil and gas industry's leadership, immersion suit protection is now unsurpassed anywhere else in the world. New developments in aviation liferafts should be evaluated as to their merit in the industry's overwater operations.

Improved energy absorbing fuselages, landing gear and seats are options which merit consideration in new acquisitions, however it may not be possible or practical to retrofit existing helicopters with these items. Incorporation of these enhancements will inherently improve the performance of the shoulder and seat restraint harness and are therefore desirable.

Wire warning systems desirable for land operations which require any degree of low level flying, particularly in hilly or mountainous regions. These devices can be fitted to any helicopter and their requirement can be assessed for individual operations or helicopter. As technology improves the performance reliability of these devices, it appears they will become a desirable option for any helicopter operation.

Flight data recorders may eventually be required for commercial helicopter operations. They greatly contribute to flight safety programs and should be seriously considered. Consultation with regulatory authorities would assist in determining requirements and possible future regulation compliance.

4.0 CONCLUSIONS (Cont.)

The Canadian Petroleum Industry should continue to monitor developments in the areas covered in this report and other safety related areas. With ongoing safety advancements and new technology in the aviation industry, it will be important to remain abreast of these developments in order to assess requirements and potential safety enhancements.

BIBLIOGRAPHY

Aircraft Crash Survival Design Guide - Volumes I, II, III, IV, V
U.S. Army Research and Technology Laboratories,
Fort Eustis, Virginia, 1980

Analysis of Rotorcraft Crash Dynamics for Development of Improved Crashworthiness Design Criteria
By Coltman; J. W., Bolukbasi, A. O. and Laananen, D. H.
Federal Aviation Administration, June, 1985

An Assessment of Underwater Lights for Use in Helicopters
By Allan, J. R.; Brennan, D. H. and Richardson, G.
Augusat, 1987
Royal Air Force, Institute of Aviation Medicine

An Examination of Problems Associated with the Waterbourne Behaviour of Helicopters
By Williams, D. L.
September, 1987

Annual Report 1986
Canadian Aviation Safety Board

Aviation Occurrence Reports, Issue 1, 2, 3, 4 and 5
Canadian Aviation Safety Board

Cause Factor: Human, A Treatise on Rotary Wing Human Factors
By Skjenna, O. W.
Health and Welfare Canada, 1981

Harper's Aircraft Book, 1913

Injury in U.S. Army Helicopter Crashes, Oct., 1979 - Sept., 1985
By Shanahan, D. F., Armed Forces Institute of Pathology
Washington, D.C.

Relative Risk, The True Measure of Safety
Paper presented to the 28th Aviation Safety Seminar, Flight Safety Foundation, April, 1983, by Roy G. Fox

Report of the Commission of Inquiry on Aviation Safety, Volume 1
Department of Transportation, 1981

Review of Helicopter Airworthiness
Report of the Helicopter Airworthiness Review Pannel (HARP) of the Airworthiness Requirements Board, 1984

Study of the Influence of Shoulder Harnesses in Aviation Safety
Report No. 87-SP0002
Canadian Aviation Safety Board, 1987

BIBLIOGRAPHY (Cont.)

Summary of 27 Helicopter Ditchings in the North Sea
Courtesy of Capt. (N) C. J. Brooks, Deputy Chief, Defence and Civil Institute of Environmental Medicine, Toronto, Ontario
Oct., 1988

United States Navy Emergency Escape Summary
Report of Aviation Emergency Escapes for Calendar year 1983, 1984, 1985
Naval Safety Center, NAS Norfolk, VA

Wilbur Wright, January 15, 1909

ANNEX "A"

This Annex contains promotional material received from manufacturers and suppliers of helicopter safety related equipment. This material is limited to those manufacturers who responded to our request for information and in no way reflects our opinion of the quality of the product or our preference of the manufacturer.

A - 1

ENERGY ABSORBING DEVICES

SUPER PUMA
AS 332

ANTI-CRASH PROTECTION

THEORETICAL APPROACH

SURVEY OF CRASHES

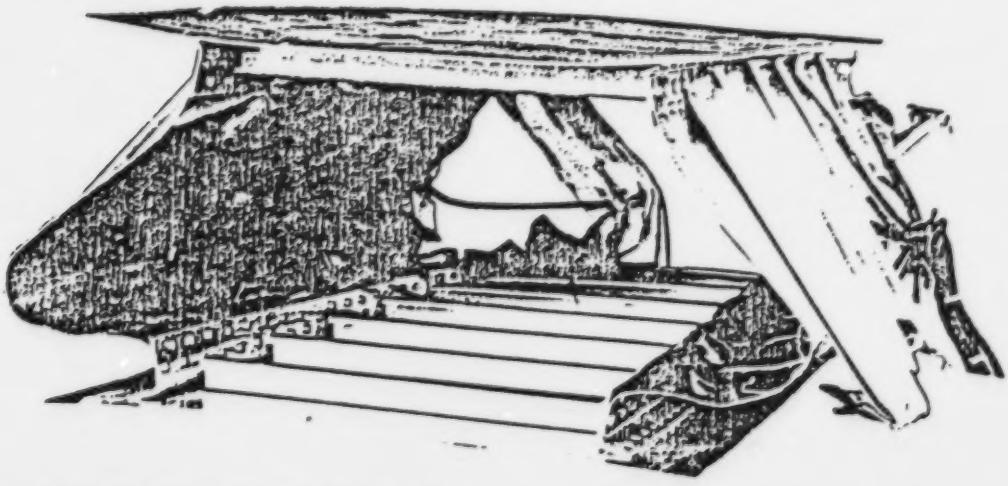
The first phase consisted in an elaborate survey intended to find out the causes and consequences of the various helicopter crashes which occurred in the world. The thorough examination of crashed aircraft made it possible to better know the helicopter structural deformation at the impact on ground and its effects an the human body.

The survey took into consideration only the so-called "survivable" crashes i.e. those with at least one survivor even if the structure was severely damaged.

LABORATORY TESTING ON PARTIAL ELEMENTS

During the crash, most of the energy is usually absorbed by deformation of the underpart of the fuselage.

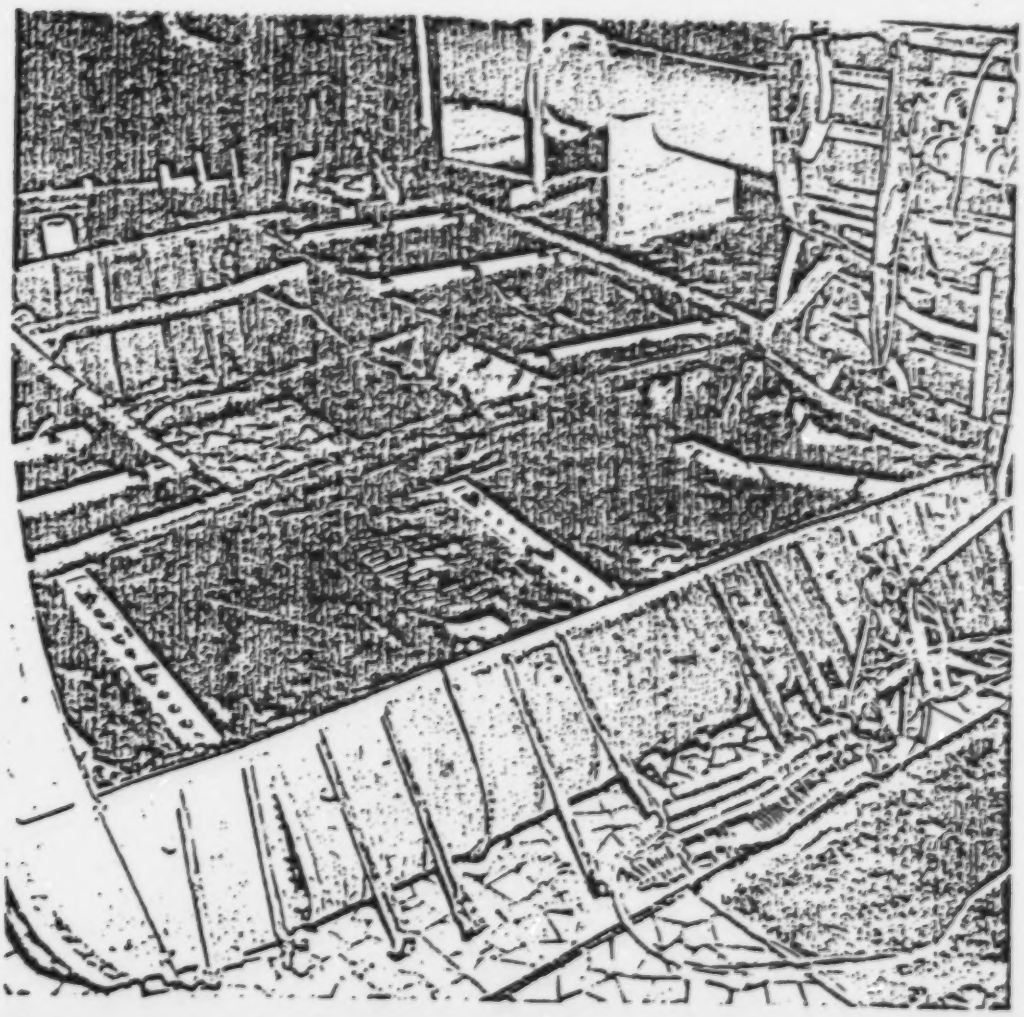
Therefore, the second phase concerned the comparative study of various components of fuselage lower structure during static and dynamic tests conducted in laboratory. Energy characteristics which have been evidenced allowed to find out the best weight-cost-efficiency compromise.



Metal box structure collapsed during the tests. The picture shows how the components distort and absorb the energy under an impact.

TESTS ON STRUCTURES

These tests were intended to compare results obtained on partial components with the phenomena affecting full scale structures in crash conditions and were conducted on sections of the existing aircraft fuselage (Puma and Gazelle) ; the lower parts consisted of conventional components : stiffened booms and frames, skins fitted with stringers. Results obtained showed a perfect correlation with conclusions of tests conducted on box structures described in the previous paragraph.

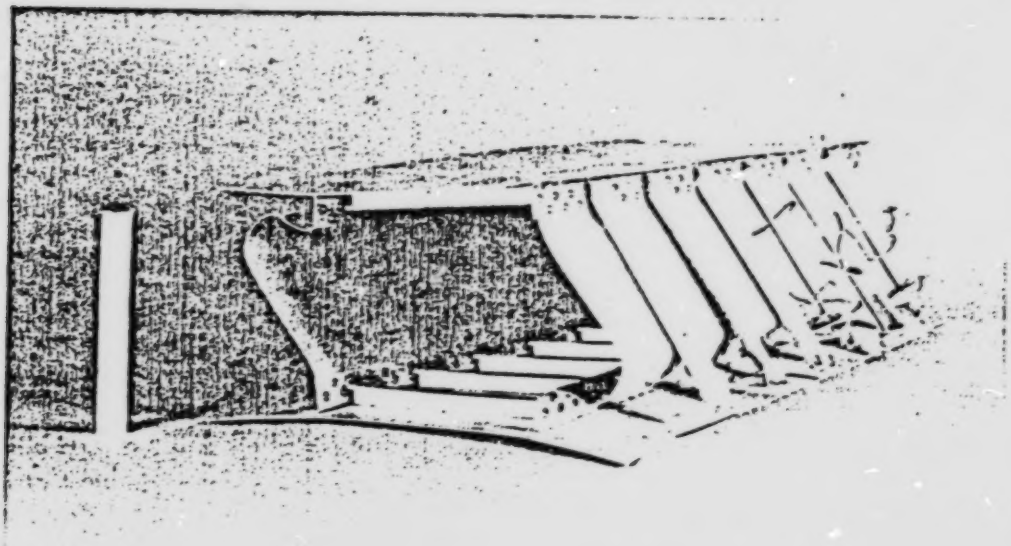


Crash test at a vertical velocity of 8 m/sec conducted on a central section of Puma fuselage : good behaviour of the fuselage ; the energy has been absorbed only by the lower elements. The rest of the fuselage and the cabin space are preserved.

TESTS ON METAL MODELS

Conjointly with the full scale tests, an important research programme is being developed on 1/3 scale metal models reproducing the aircraft structure accurately. This method allows dynamic tests to be carried out rapidly and at the minimum cost on structural assemblies or elements without waiting for a complete aircraft to be available.

The technological development tests proved that the behaviour of these models is very comparable to that of the full scale structures.



Metal model

DEVELOPMENT OF A MATHEMATICAL MODEL

The Marignane Aerospatiale Engineering Department has adapted the "KRASH" design programme in order to dispose of a means of prevision on the structural behaviour as soon as an aircraft is designed.

The applicability of the programme as well as the modelization technique have been obtained by setting up a Gazelle mathematical model and making a survey of the aircraft and occupants behaviour in conditions identical to a global crash test of the helicopter.

The comparison between the acceleration and deformation measurements and the calculated values demonstrated that the results were very consistent.

DRAWING UP SPECIFICATIONS

The experience gained by Aerospatiale during this research programme and during the tests led to draw up specifications intended to give the aircraft a high level of safety in case of crash.

From the very beginning of its design, the Super-Puma has taken advantage of the resulting improvements. The aircraft has been designed to withstand, in the best conditions, the drop velocities noted during crashes with a least one survivor. According to the statistics, 95 % of these crashes occurred at a speed of 13 m/sec maximum. Beyond this velocity, the chances of survival are practically nil since the accelerations exceed the limits supportable by the human system and imply an energy which cannot be absorbed by the structure.

CHOICE OF A STANDARD OF PROTECTION

ECONOMICAL CRITERIA

With a maximum limit of survival at an impact velocity of 13 m/sec, it appeared necessary to define an acceptable standard of protection for the aircraft and their occupants.

Economical studies show that the standard of protection considerably affects weights and prices. It is the reason why Aerospatiale had to find a compromise offering a high standard of safety while maintaining an acceptable cost/weight/efficiency ratio. The curve " % protection ratio/cost for 10 000 flying hours" locates the point of the best efficiency at 85 % (Fig. 1). This value, plotted on the cumulated crash curve corresponds to a drop velocity of 10.5 m/sec. (Fig. 2).

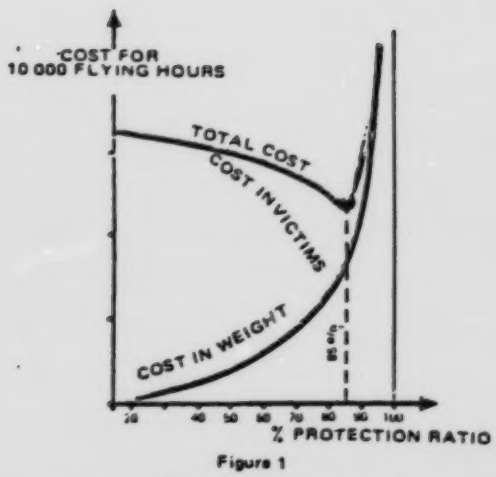


Figure 1

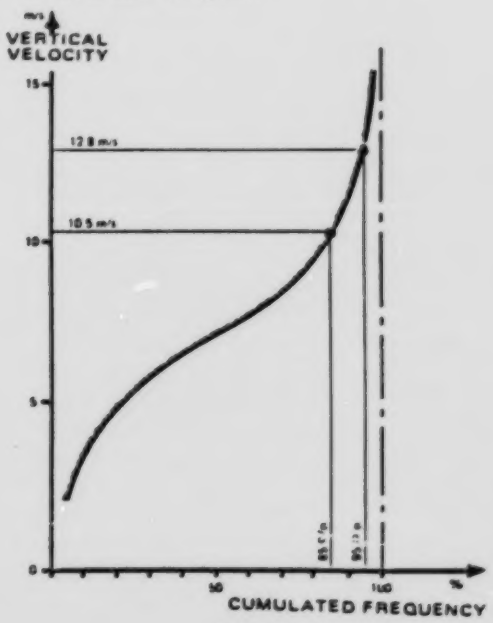


Figure 2

It is therefore this value which is taken into consideration and which made it possible to obtain an homogeneous design of the structure, landing gears, seats and fuel system.

APPLICATIONS TO SUPER PUMA AS 332

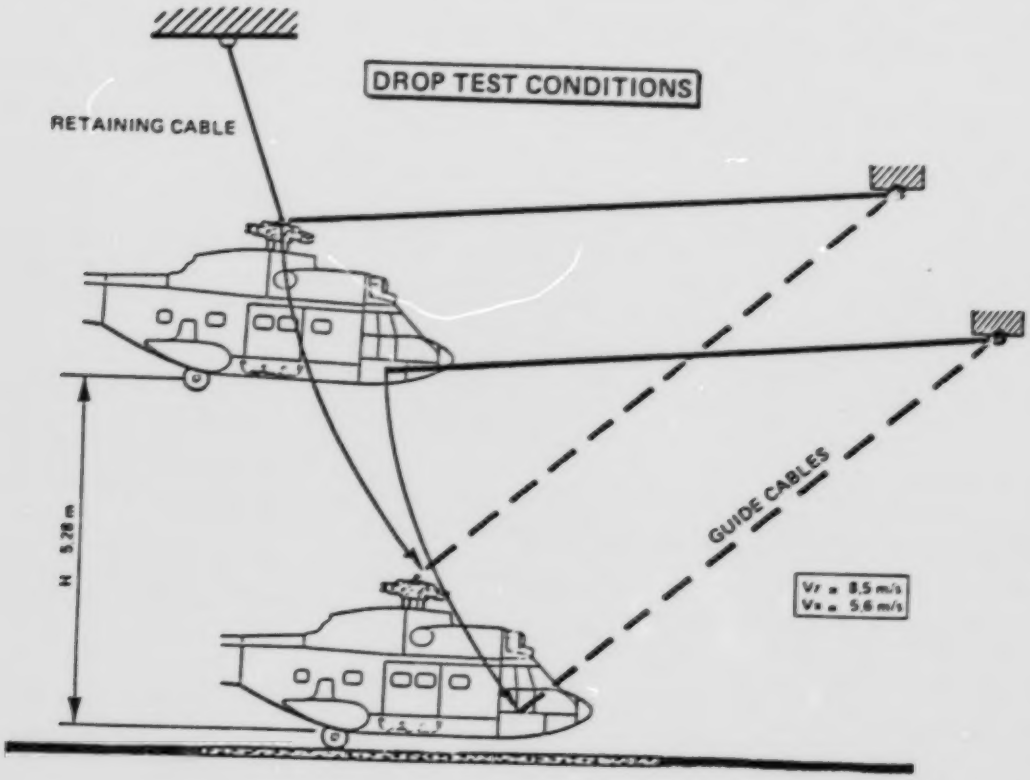
TESTS ON COMPLETE STRUCTURE OF THE SUPER PUMA

From the technical experience previously described Aerospatiale studied a complete aircraft structure.

This structure was fitted with some crash-worthy equipment (cabin floor – fuel system – mechanic's pilot's and troops' seat) which formed the subject of separate studies and developments.

The landing gear which was tested later, was not included in the anti-crash tests which took place in June 78 at the "Centre d'Essais Aéronautique de Toulouse" in the following conditions :

- vertical velocity of 8.5 m/sec. This value compensates the absence of landing gear which absorbs 25 % of the total energy ; this corresponds to the selected velocity of 10.5 m/sec. for the complete aircraft.
- horizontal speed of 5.6 m/sec.



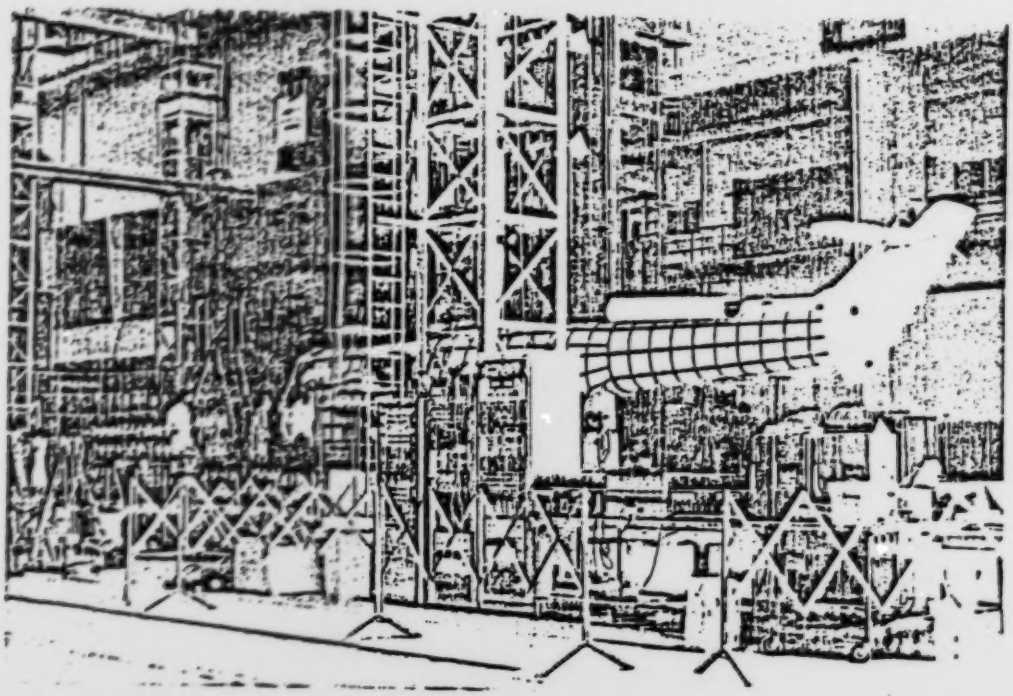
Among the important means implemented for this test, one can quote a rocker gantry which makes it possible to re-create the "pancake" drop conditions.

– 44 accelerometers on the structure, 69 on the dummies, 37 strain gauges, 6 pressure sensors in the tanks and 13 other sensors allowed the recording of 169 parameters.

– The aircraft behaviour was filmed from various points and under various angles by cameras operating at various speeds. The floors, landing gear and engine attachment areas had been modified to make the SA 330 Puma airframe used for the test, identical to that of the AS 332 Super Puma.

– Equipment included 2 pilot's seats of different types, 1 mechanic's seat and various types of crashworthy troop seats identical to the versions being developed ; the test was intended to compare their respective behaviour. These seats were occupied by dummies fitted with several acceleration recorders.

– The airframe also contained 5 crashworthy tanks of different types and fitted with internal pressure sensors to study their respective crushing resistance.

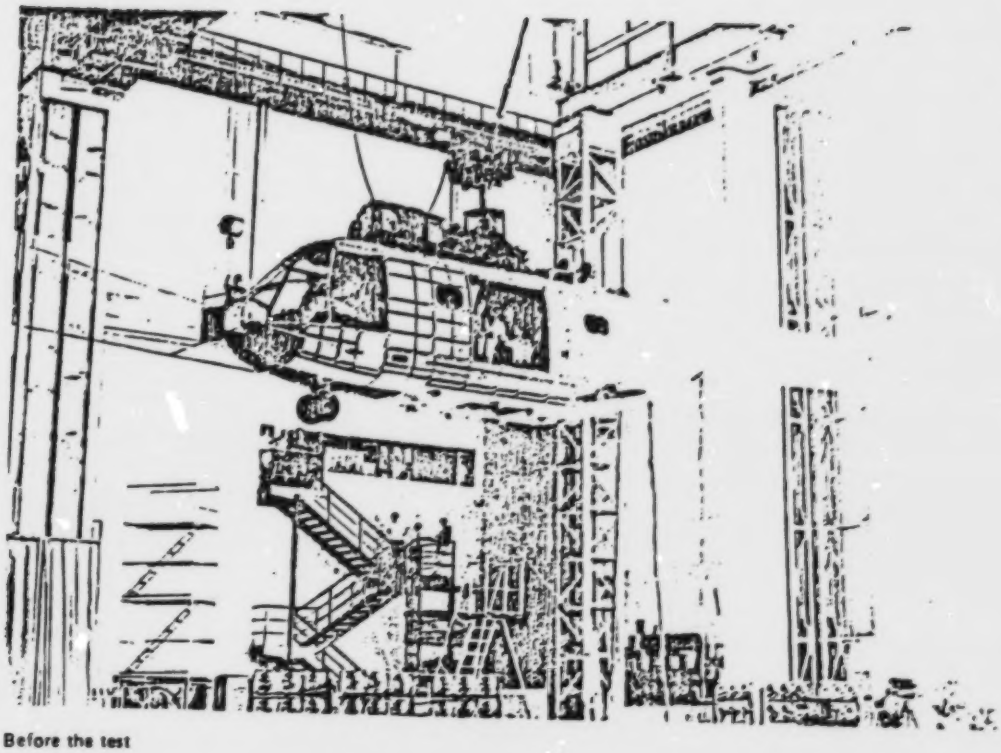


Measuring equipment installation

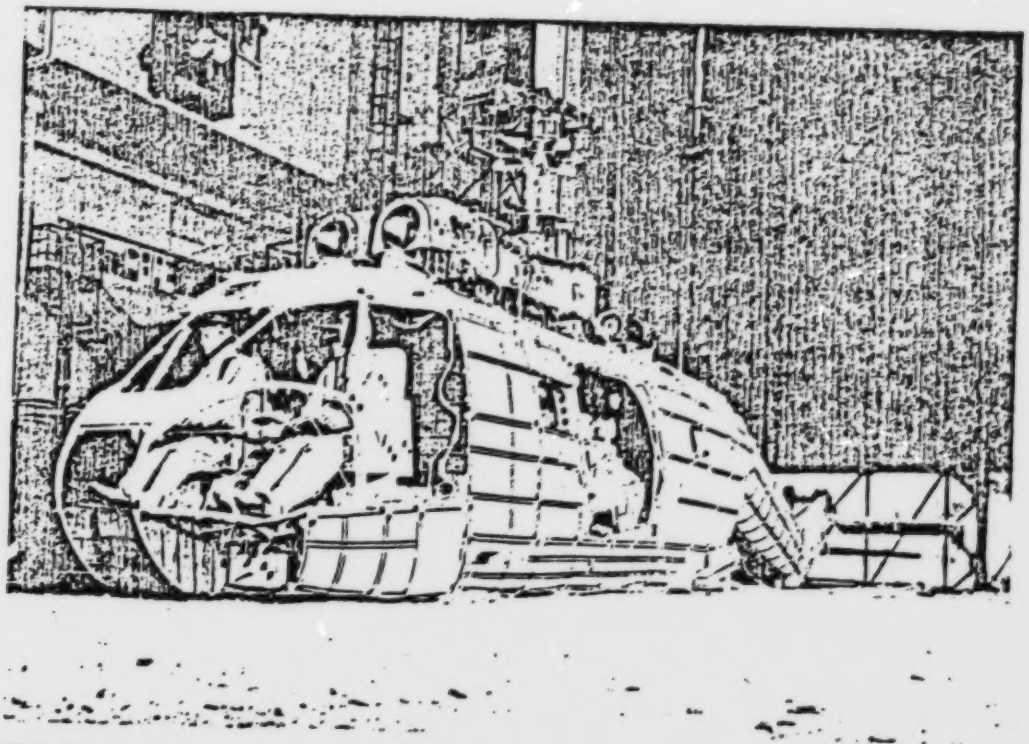
RESULTS

Results were consistent with the previsions.

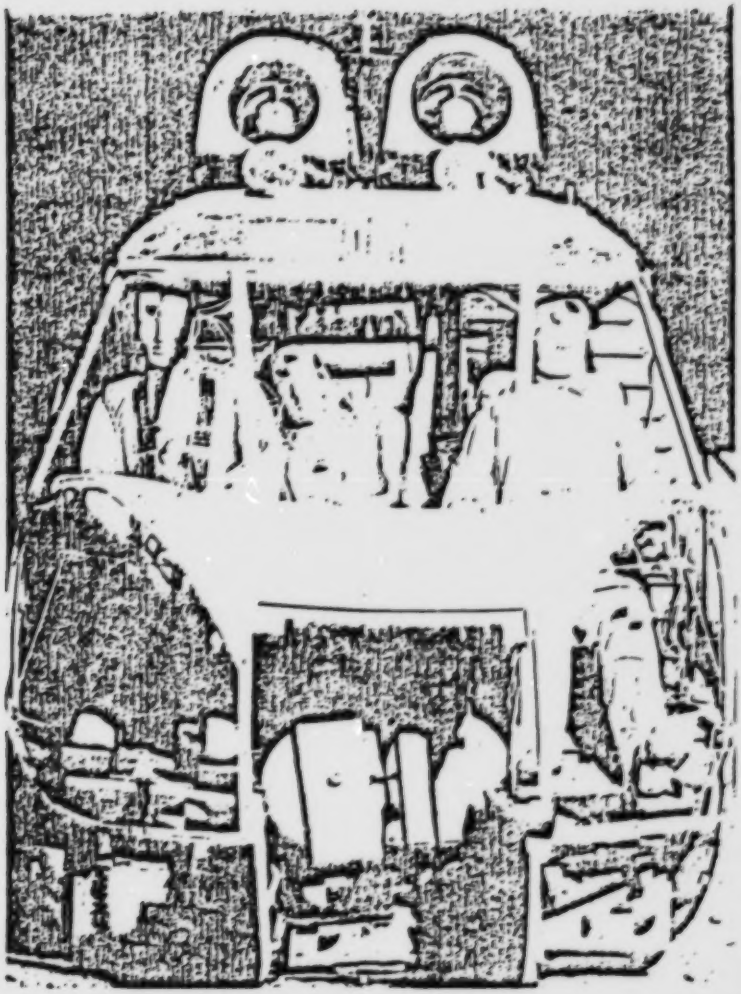
- Most of the energy has been absorbed by the airframe bottom with a 60 to 70 m/m crushing.
- The cabin volume has not been highly reduced.
- Cabin floors have been slightly distorted.
- No heavy element (main gearbox or engines) separated from the attachment points.
- Most of the crashworthy seats fulfilled their function : the vertical acceleration levels at various points of the dummies did not exceed the envisaged maximum level of 20 g in 0.1 sec.
- The types of tanks selected for further installation on the production aircraft were not damaged at all (tears, explosion or perforations).



Before the test

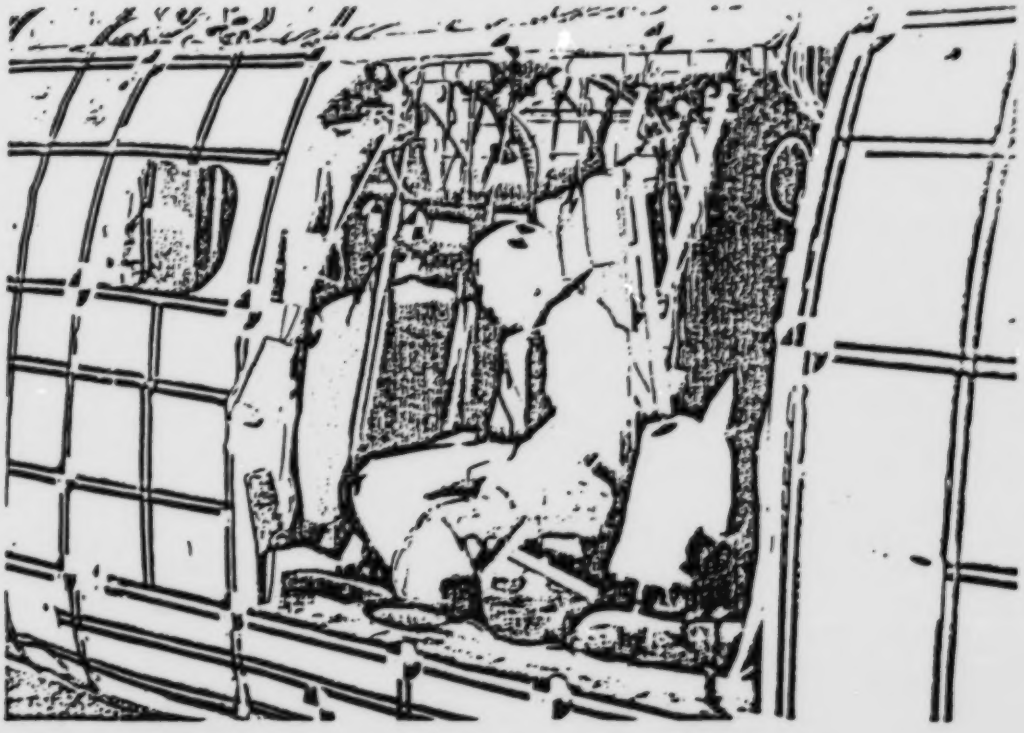


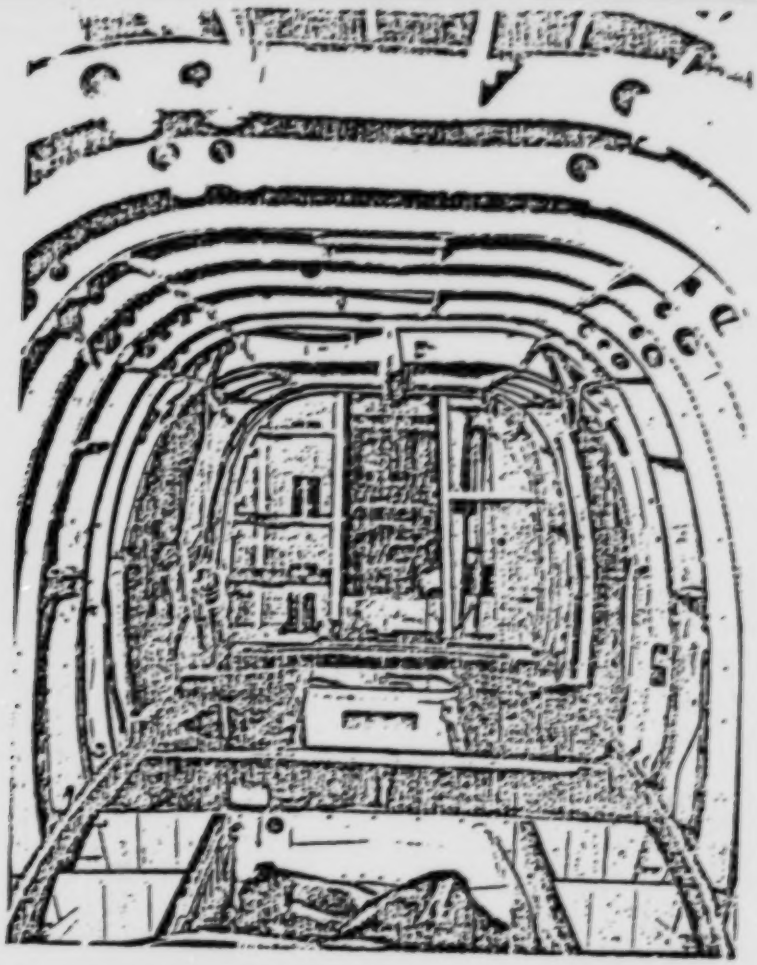
After the test



Front view of
the pilot's station

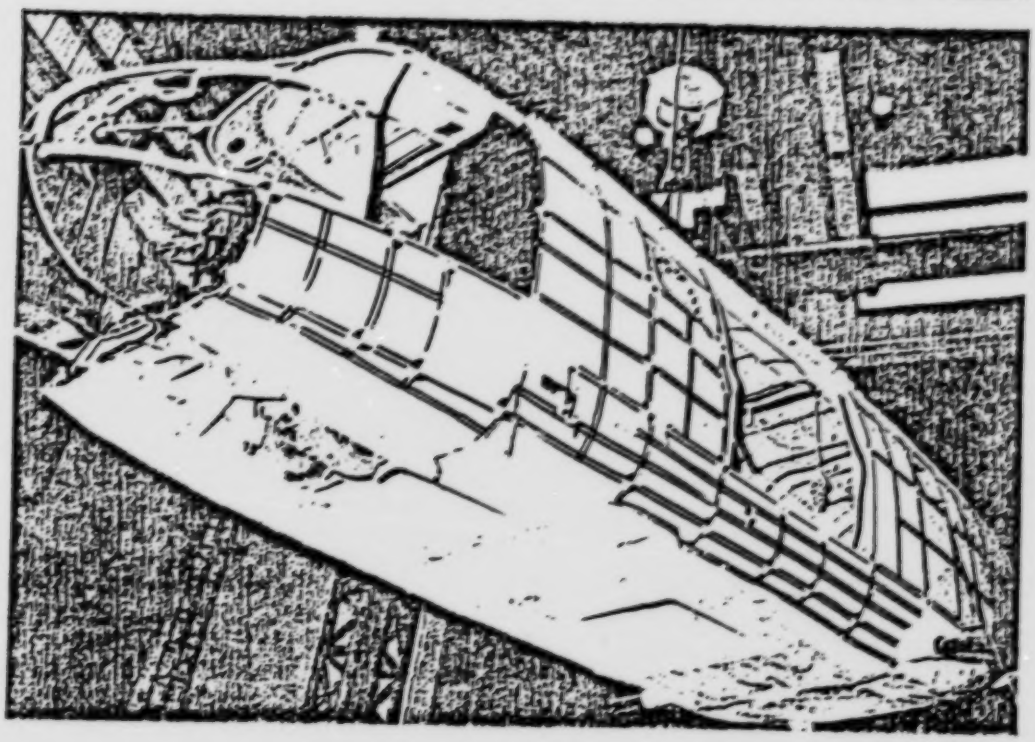
Troop seats





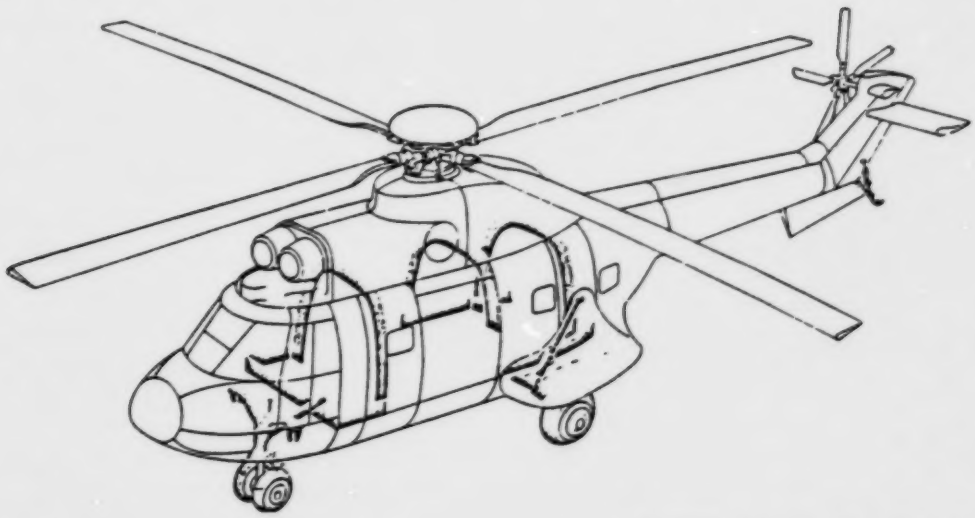
Inside of cabin
after test

Bottom view of the structure

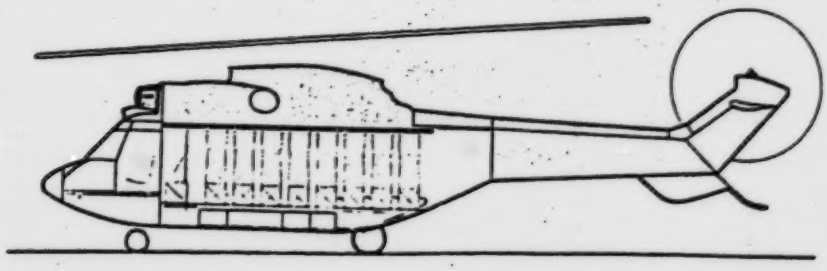


DESCRIPTION OF IMPROVEMENTS STUDIED AND APPLIED ON SUPER PUMA AS 332

RECAPITULATION



Structural reinforcements and landing gear



Installation of seats, fuel tanks, cockpit and cabin floors

STRUCTURAL REINFORCEMENTS

As compared with the basic airframe of the SA 330 Puma, the airframe of the AS 332 Super Puma has been provided with various structural reinforcements intended to make the aircraft capable of withstanding the considered impact velocities :

- **Reinforcement of the cabin floor :** by duplicating the floor-to-structure attachments in order to withstand the two types of efforts due to the impact : upward pressure caused by the tank pressure and downward pressure due to the various loads (seats, pallet, etc ...)
- **Pilot's floor :** reinforcement of the seat rails, their attachment to the floor and of the floor itself to ensure an efficient behaviour of the crashworthy crew seats.
- **Main landing gear attachment frames:** modified with respect to the SA 330 due to the different design of the landing gear whose resistance has been improved.
- **Engine and main gearbox attachment points :** reinforcement of the upper part of the frames supporting the heavy elements (engines, main gearbox).
- **Tail boom :** two improvements were made due to the important proportions of crashes occurring in nose up positions — these improvements consist in reinforcing the tail boom at its attachment to the body structure and in fitting an energy absorber on the rear section in order to deaden the impact on ground.
- **Addition of a longitudinal beam:** on the baggage hold ceiling for the crashworthy seat attachment.

All these modifications which were embodied in the AS 332 airframe used in the crash test proved their efficiency (only the rear energy absorber was not fitted since the test concerned a "pancake" drop).

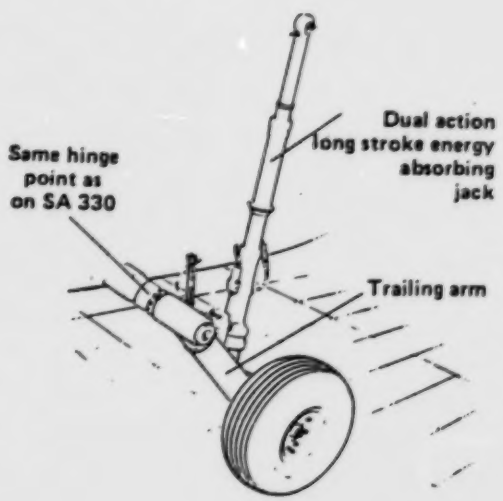
LANDING GEAR

The main landing gear has been completely re-designed to satisfy the energy absorption requirements on normal and severe landings and during crashes.

The "trailing" arm type landing gear has been adopted. This design makes it possible to absorb a high level energy due to the important available travel of the damping jack, the trailing arm hinging about a point secured to the aircraft structure.

This landing gear assumes the following functions :

- landing- taxiing
- retraction in flight
- anti-crash
- kneeling

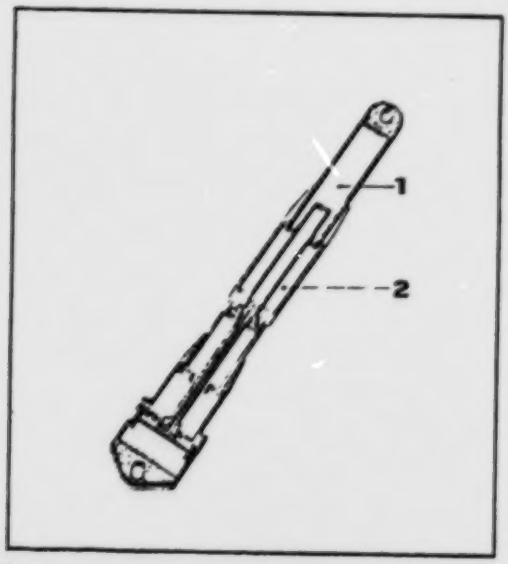


The damping jack consists of various chambers whose functions are as follows :

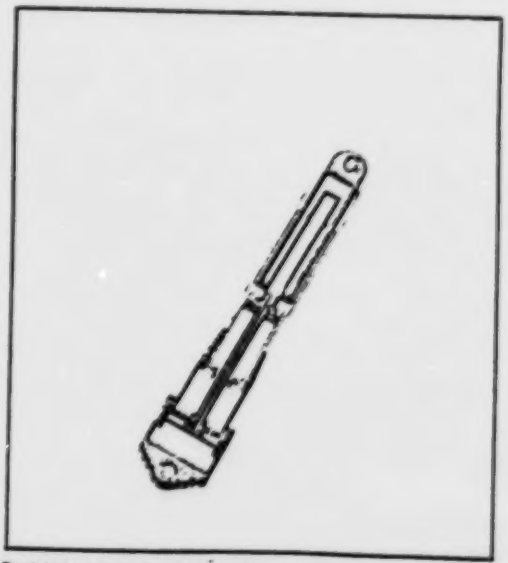
- On normal landing phase up to 3 m/sec

The energy absorption is achieved by the passage of the hydraulic fluid from chamber 2 into upper chamber 1 through calibrated orifices and by compression of the gas contained in chamber 1.

After landing, the assembly takes a compressed rest position.



Position before impact on ground



Position at impact on ground

- **Hard landing up to 6 m/s**

The energy absorption is achieved in 2 phases. During the first phase the liquid flows from chamber 3 to chamber 4 through orifices adequately calibrated. During this phase, piston of chamber 4 compresses the gas contained in the lower part (absorption from 6 to 3 m/s, which corresponds to the conditions of the 3 m/s landing phase described above.

- **Hard landing above 6 m/s**

For impacts between 6 m/s and 10 m/s, the second oleopneumatic device is able to operate due to variable restriction orifices.

At the end of travel, bursting of the tyres and wheel before the structure has hit the ground, absorbs additional energy so that the total energy absorbed by the main landing gear remains constant at any impact velocity. As previously mentioned the energy absorption of the landing gear represents 25 % of the total energy to be absorbed, which reduces the impact velocity from 10.5 m/sec. to 8.5 m/sec. and places the structure in the conditions of the crash test performed in Toulouse.

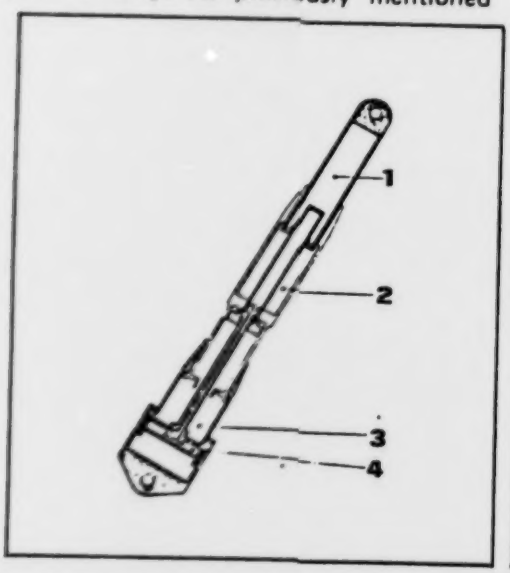
The conventional nose landing gear which is basically the same, has been reinforced.

A tail guard fitted with an energy absorber allows tail down landings.

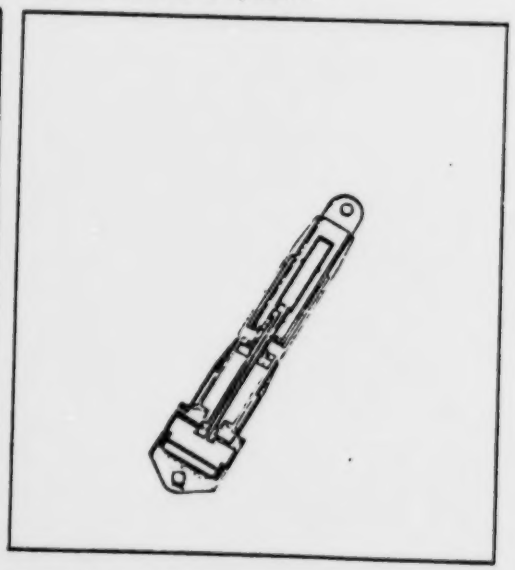
The principle of the tail guard lies in the deformation of a metallic tube subjected to a constant load which is therefore independent of the impact velocity.

The main landing gear therefore assumes the main function since if the landing affects first the nose wheel or the tail guard, the shock causes a complete rotation of the aircraft and a loading of the main landing gear.

The secondary functions such as retraction in flight or kneeling on ground are controlled by the pilot by expelling the hydraulic fluid out of chamber 3 through the pipes of the hydraulic system.



Position before impact on ground



Position after the crash

CRASHWORTHY SEATS

Designs, test and development concerned the 3rd man's and troop seats.

Type tests conducted at the "Centre d'Essais Aéronautique de Toulouse" made necessary the realization of an acceleration carriage designed to test these seats in various configurations and at various acceleration thresholds. These tests allowed measuring accurately the behaviour of assemblies, loads and stresses applied to the various areas as well as the resulting acceleration levels affecting the various points of the dummies. All these tests have been filmed by cameras operating at 500 frames/second.

Several types of energy absorbers which must be fitted on these seats have been previously designed and tested in laboratory.

ENERGY ABSORBERS

Their main function consists in reducing the accelerations to a level which can be supported by the human system ; in fact, these accelerations can reach a very high level during a crash. These absorbers which are located between the aircraft structure and the seat operate according to the principle of a high deformation under a constant effort. The type of energy absorbers adopted consists of a special elastomeric cartridge enclosed in a metal cylinder one end of which is secured to the seat base. A metal rod ended by a knife shaped blade is inserted into the hole located at the other end of the cartridge and is attached to the aircraft structure. In static position, the assembly is made integral through a shear or tension rupture system.

During the crash, the pin breaks and the knife enters progressively the elastomeric cartridge thus providing the desired energy absorption.

Energy absorbers

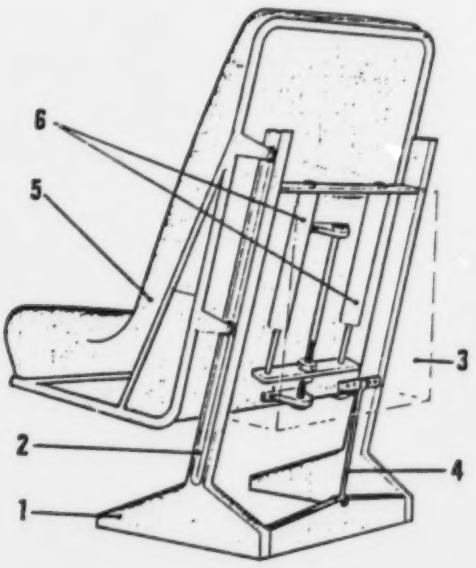
Pilot's seat. The seat adopted for the Super Puma consists of :

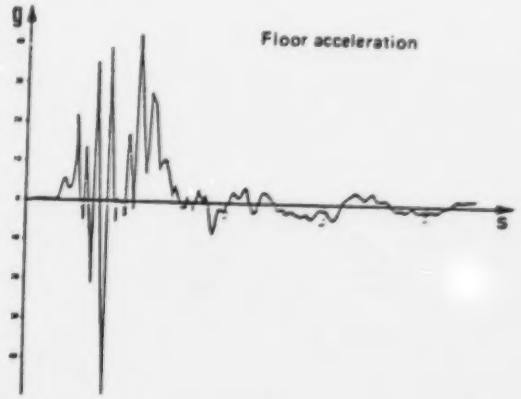
- A lower base (1) fitted with rollers for the longitudinal displacement of the seat along the floor rails. This base includes 2 vertical rails (2) for the adjustment in height of pan seat (5). A box structure (3) which supports these rails ensures the stiffness of the base ; its rear lower section includes a calibrated rod (4) connected to the lower base.
- A pan seat (5) which can be armour plated as an option.
- Two energy absorbers (6) interconnecting the seat back and the box structure.
- A system of reel straps and harness — During a vertical crash the seat pan is restrained by absorption system (6) during its downward motion — the so obtained acceleration level is 15 to 20 g in 0.1 s i.e. less than the maximum level which can be tolerated (25 g in 0.1 s).

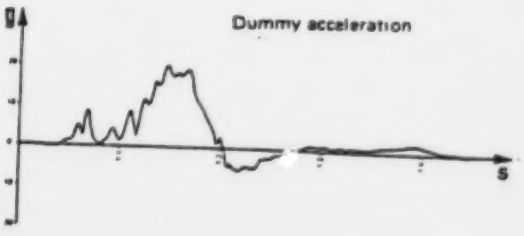
During a nose crash, the vertical rails pivot, at their lower part, around their embedding point while creating an extension of the calibrated rod (4). The energy absorption results from the rail bending and the rod extension and makes it possible to reduce the acceleration level to 17 g in 0.1 sec. i.e. less than the maximum level which can be tolerated (40 g in 0.1 s).

The seat also abosrbs the lateral or combined energies.

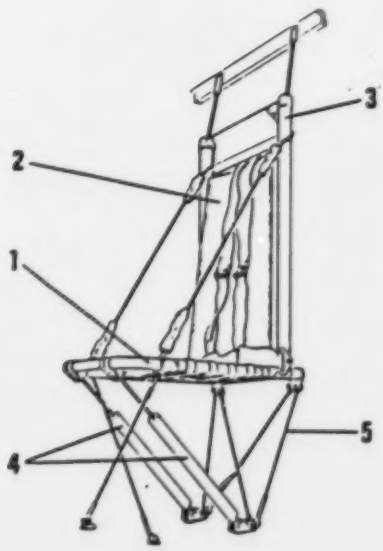
During the Super Puma crash test, the acceleration on the dummy was 20 g for a seat travel of 45 m/m, whereas they were 42 g on the floor. The total travel of 120 m/m makes it possible to cope with extreme conditions.



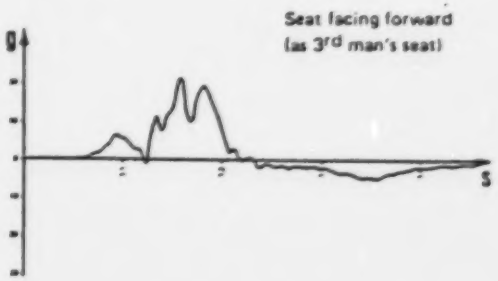




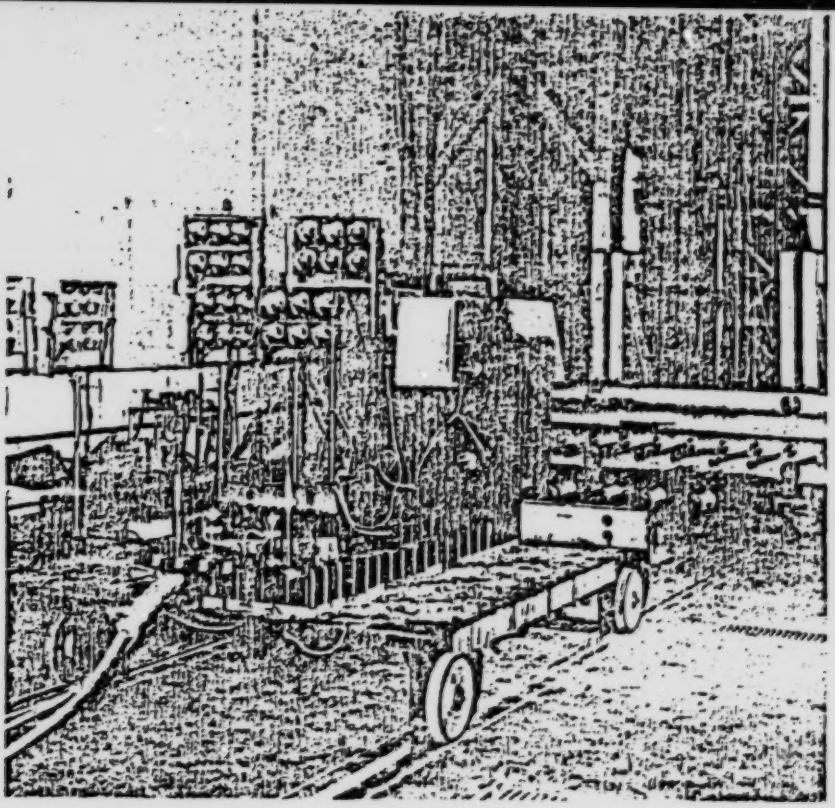
- **Troop seats.** They consist of a netting (1) and a back (2) of light alloy tubes covered with fabric. Each of both vertical posts includes internally an energy absorber (3) attached to the cabin ceiling. The netting is connected to the floor by 2 energy absorbers (4). Cross-braced cables connecting the netting to the floor ensure the stiffness of the seat when in position, the assembly being tensioned, at the upper end, by a snap fastener system. These seats are fitted with inertia harness. They have been subjected to several acceleration rig test and were installed in the airframe when the Super Puma crash test was conducted at C.E.A.T..The type of seat selected for the production AS 332 gave good results in lateral position as well as facing forward. For floor accelerations of 65 g, the accelerations were 23 g in 0.1 sec. on the dummies in vertical crash, which is an acceptable value.



The troop seat facing forward is positioned in the same configuration as the 3rd man's seat.

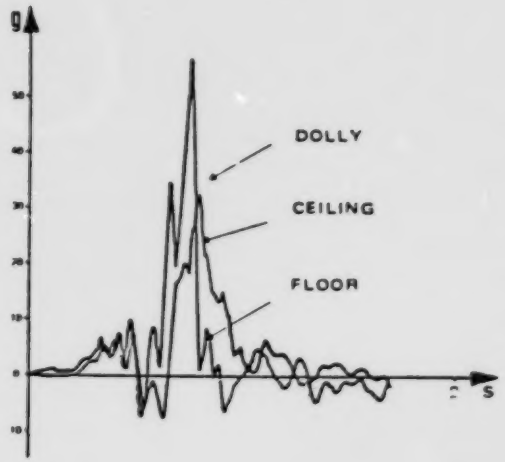


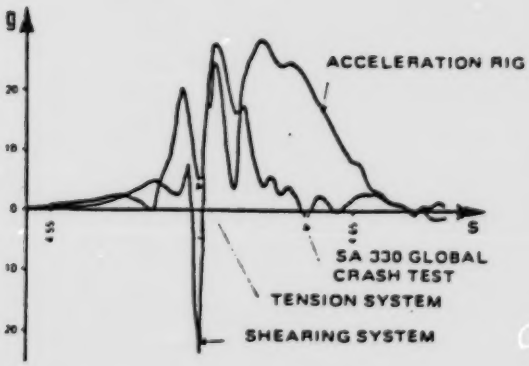
- **3rd man's seat.** This seat which can be compared to the troop seat, differs from it only by its quick disconnecting system and by its stowage against the electrical equipment cabinet, such provisions, being necessary because of the various functions of the mechanics (access to the pilot's station or evacuation through the baggage hold). The 3rd man's seat is fitted with a reel harness which allows the 3rd man to reach certain controls.



- **Development of seats on acceleration rig.** This rig which has been developed at C.E.A.T. makes it possible to produce in a repetitive and controlled way, an acceleration profile comparable to that recorded in the structure during the test.

  The profile range used for the seat development exceeds that of the accelerations recorded on the floor : therefore, the seats developed on the acceleration rig will behave better in true conditions.

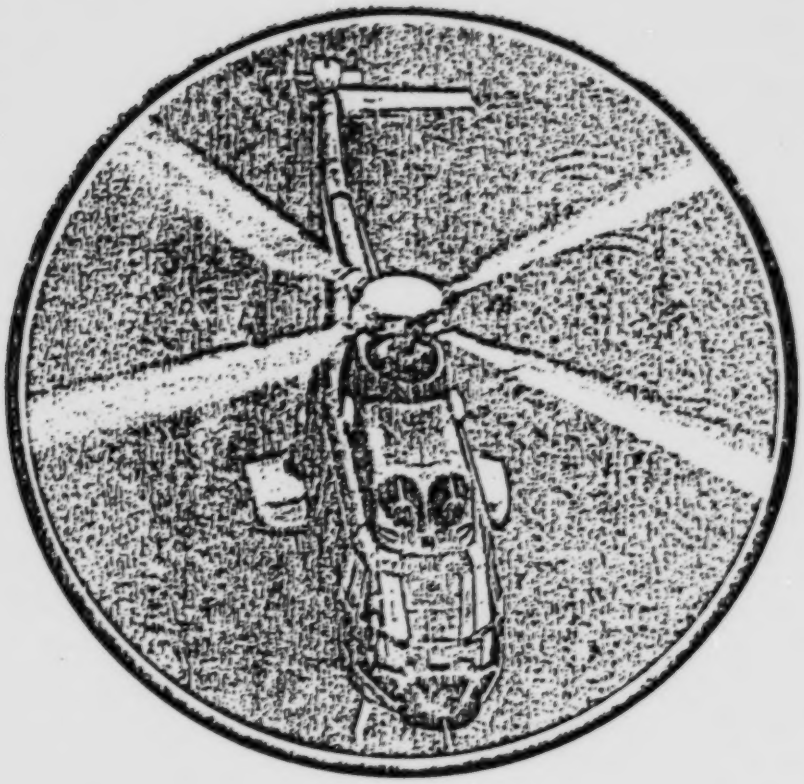




The graph to the right shows an example of improvement of the absorbing system thanks to the acceleration rig. Originally, the knife was made integral with the damper body by a shearing system. As the shearing rupture was too rapid, the shock caused an unacceptable negative pre-acceleration on the occupant. Replacing the shearing system by a tension rupture system has eliminated this drawback.

A - 2

CRASHWORTHY FUEL SYSTEMS



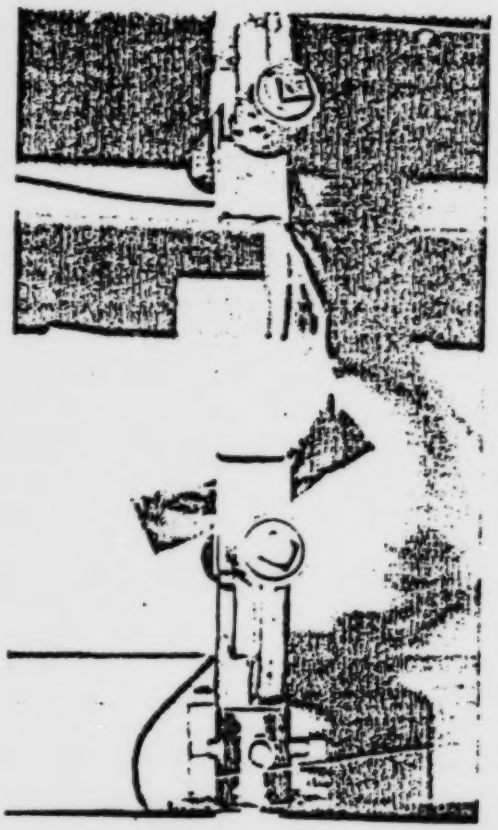
SUPER PUMA
AS 332

ANTI-CRASH PROTECTION

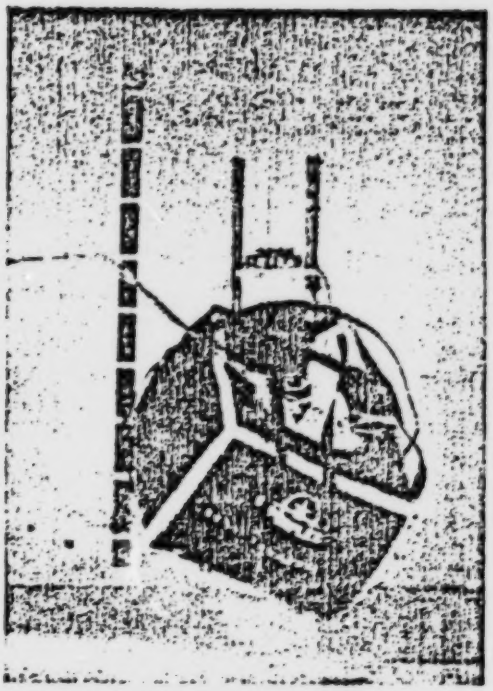
FUEL SYSTEMS

Fuel systems are the prevailing elements in the aircraft safety ; it is the reason why they have been the subject of a particular attention : crashworthiness has been studied in order to reduce any risks of explosion, fuel outflow or fire as far as possible.

- **Pipes.** All feeding, intercommunication or air vent pipes are flexible and resistant ; due to their position and their constitution they can absorb important structural deformations.
- **Fuel system equipment supports.** They are embrittled in order to remain integral with the fuel system (pipes or tanks) during a crash and consequently to avoid any leaks.
- **Anti-overflow valves fitted on air vents.** Pipes are fitted, at their end, with a ball valve which prevents a possible fuel outflow if the aircraft capsizes during a balked landing.
- **Fuel shut-off lever.** 2 levers easily accessible by the crew make it possible to cut off immediately the engine fuel supply in case of emergency landing. They also cut off the electric system.
- **Fuel tanks.** The fuel tank walls have been designed to withstand high internal pressures they are submitted to during the crash and therefore to avoid the explosion of the tank and any fuel spray which may cause an immediate fire. The material used for tank walls make them resistant to tearing or penetration (perforation by a structural element for example).



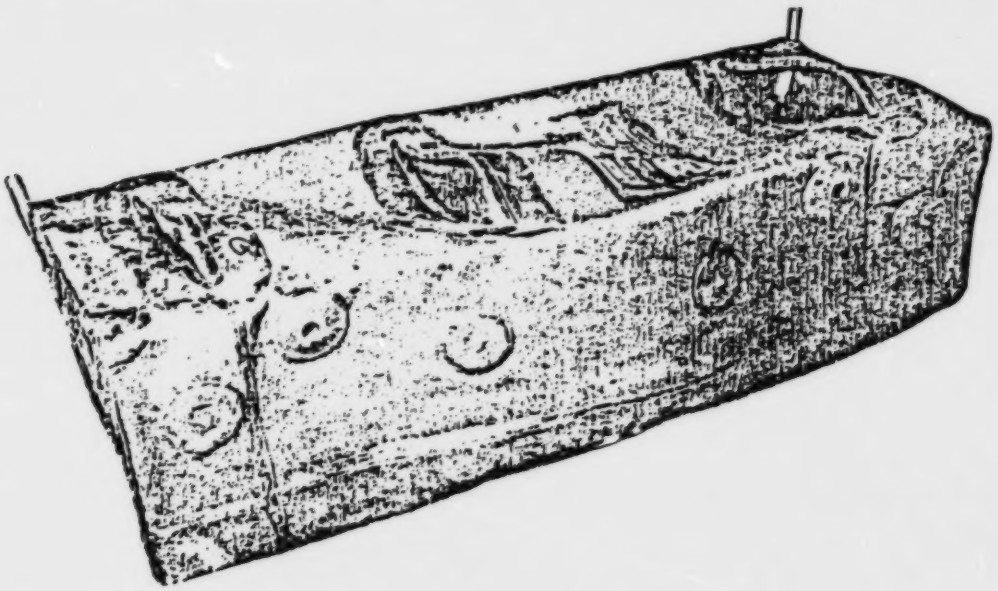
Tearing test of a wall



Drop test of a cubic fuel tank conducted at C.E.A.T.

The several tests conducted on the fuel tank wall or on the fuel tank assemblies were subjected to an official approval in the Government laboratory. So, the drop tests performed on full tanks at 14 m/sec ensure an important safety margin with respect to 10.5 m/sec velocities evidenced during severe crashes.

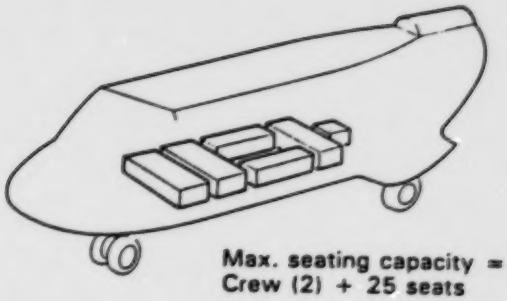
Three types of fuel tanks designed from these tests have been fitted on the airframe utilized during the anti-crash testing. The most crashworthy fuel tank has been selected for the production aircraft.



Fuel tank selected shown after the test : no damage was evidenced

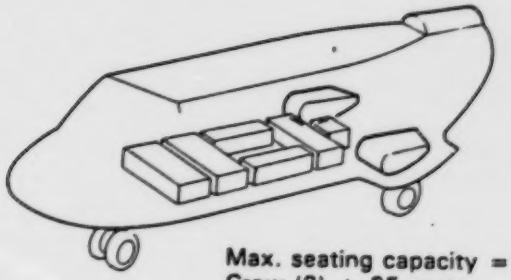
FUEL CAPACITY

– Basic
(a/c equipped with optional crashworthy fuel tanks)
2,008 litres



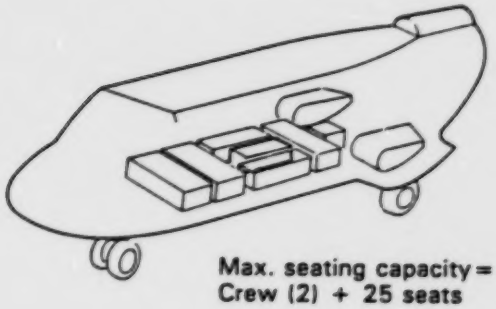
Max. seating capacity =
Crew (2) + 25 seats

+ External tanks
(crashworthy type - 2 × 333 l
Equipment weight = 122 kg)
Total = 2,674 litres



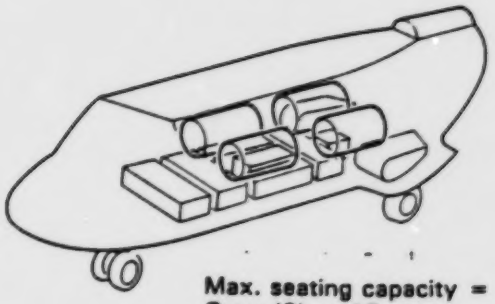
Max. seating capacity =
Crew (2) + 25 seats

+ Central auxiliary tank
(crashworthy type - 318 l
Equipment weight = 21 kg)
Total = 2,992 litres



Max. seating capacity =
Crew (2) + 25 seats

+ 4 internal tanks
(4 × 475 litres -
Equipment weight = 4 × 20 kg)
Total = 4,892 litres

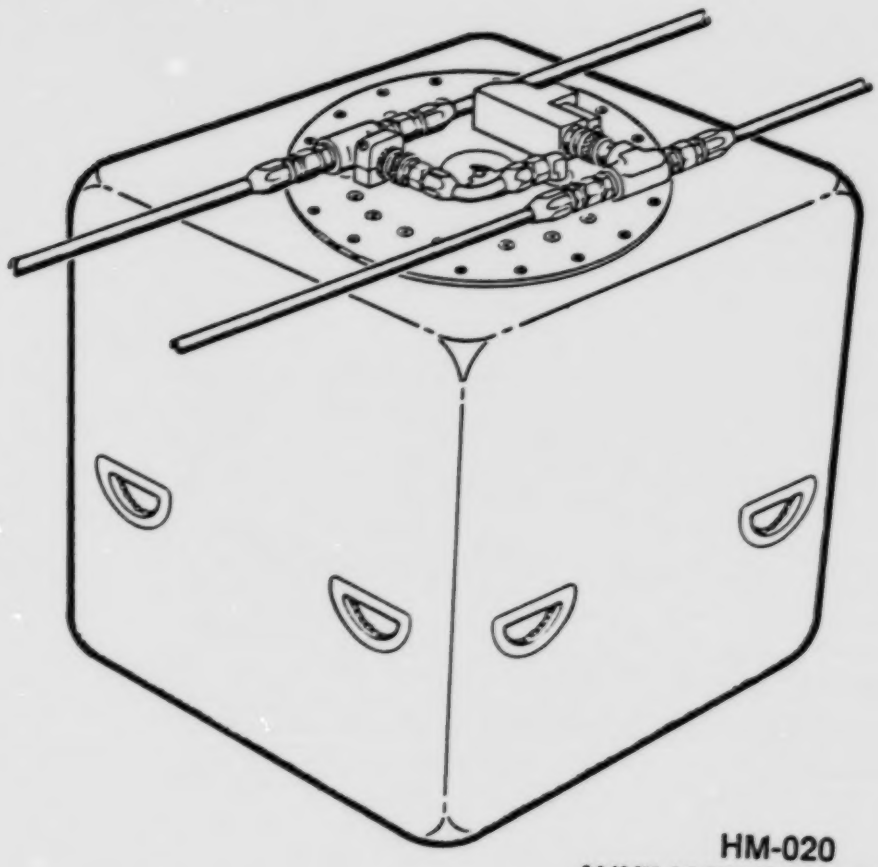


Max. seating capacity =
Crew (2) + 15 seats
with 1 tank to 5 seats
with 4 tanks

GUARDIAN Auxiliary Fuel System

MODEL HM-020

by ROBERTSON Aviation, Inc., the worlds leader in the design, development and production of crashworthy and crash resistant fuel systems. All systems are built to U.S. Government exacting standards.



The *GUARDIAN* system

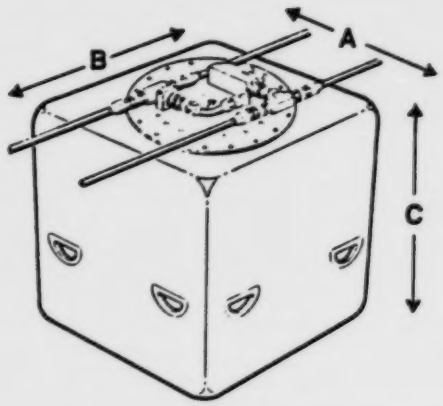
HM-020
AUXILIARY FUEL SYSTEM
...Rugged Where Rugged Counts...

- Designed for quick configuration changes needed during Rapid Deployment operations
- Can be coupled together easily to allow use of multiple tanks and sizes
- Can be taken in and out in 5 minutes or less with hands only—no tools required
- Can be filled by Single Point or Pressure refueling (Specific models only)
- Incorporates self-sealing/quick disconnect valves in fuel and vent system
- Can incorporate a rapid transfer and/or dump capability (Specific models only)
- Can be equipped with crashworthy self-sealing bladders

Robertson fuel systems are designed for rugged use in the field. They are designed, tested, and manufactured by pilot/engineers for the working pilot. Careful attention to operational detail, utilization, and appearance is demonstrated throughout each design.

— DATA SHEET —

Tank Model I.D.	HM-020-185			HM-020-400			HM-020-800		
Applicable Aircraft	Various			Various			Various		
Capacity	185 Gal. U.S.*			400 Gal. U.S.*			800 Gal. U.S.*		
Weight	169 Lbs.*			320 Lbs.*			525 Lbs.*		
Dimensions	A 34.5"	B 36.5"	C* 42"	A 48"	B 48"	C* 48"	A 58"	B 58"	C* 62"



* Approximate — Dependent on Specific Configuration.

BASIC FUEL SYSTEM INCLUDES

TANK

- Honeycomb Outer Container with Carrying Handles
- Crash Resistant Bladder
- Cavity Drain
- Removable In-Tank Plumbing Module
- Gravity Fill Opening
- Crashworthy Filler Cap
- Fuel Transfer Pump
- Quantity Scale
- Fuel Sampling System
- Rollover/Float Vent Valve
- Fuel Pressure Switch
- Self-Sealing/Quick Disconnect Valves on All Outlets

FIXED HARDWARE/PLUMBING

Designed specifically for each aircraft model. Components will vary but normally include the following:

- Self-Sealing/Quick Disconnect Valves in Fuel and Vent System
- High G Restraint Harness with Interface Hardware
- Control Panel for the Auxiliary Fuel Transfer System Including All Interconnecting Electrical Cables
- Crashworthy Hoses

CONFIGURATION OPTIONS

TANK MODEL I.D.	BASIC SYSTEM	CRASHWORTHY SELF-SEALING BLADDER	SINGLE POINT PRESSURE REFUELING	GAUGE	THESE EXTRA OPTIONS CAN BE ADDED TO ALL MODELS:
HM-020	X	....	....	....	■ Fuel Dump System ■ Unisex Type Hose End Fittings ■ Customized Dimensions ■ Dual Internal Pumps ■ Robertson or *FARE* Off Load Transfer Systems
A	X	....	X	....	
B	X	....	X	X	
C	— — — — — — RESERVED — — — — — —				
D	X	X	....	....	
E	X	X	X	....	
F	X	X	X	X	

ROBERTSON AVIATION, INC.

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FAX (602) 968-3019

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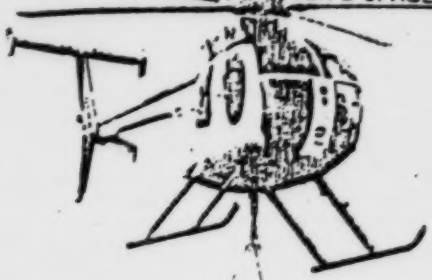
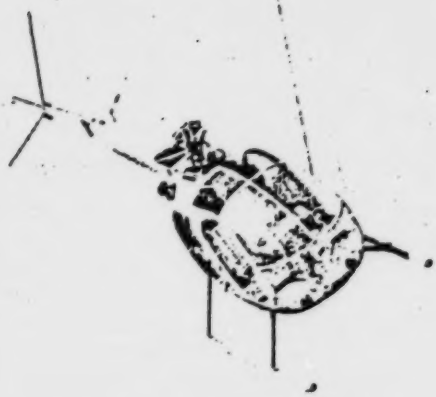
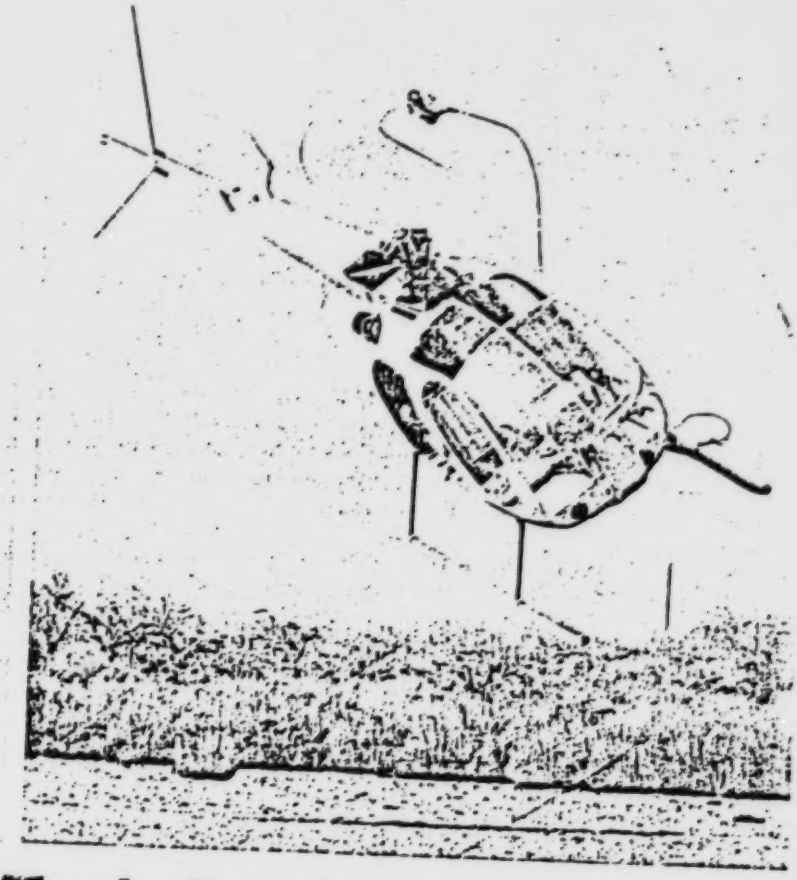
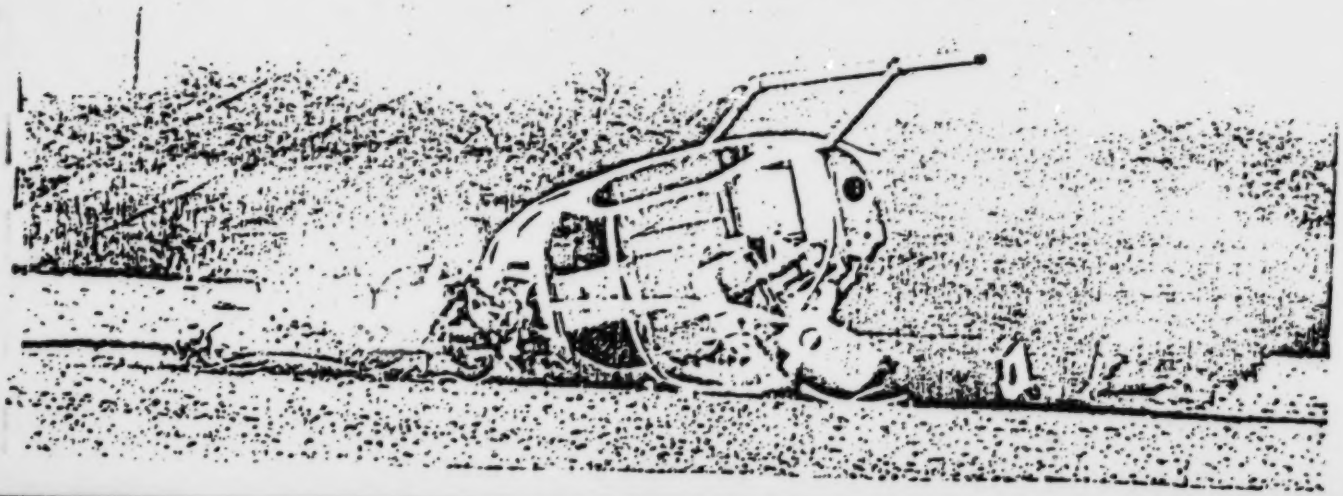


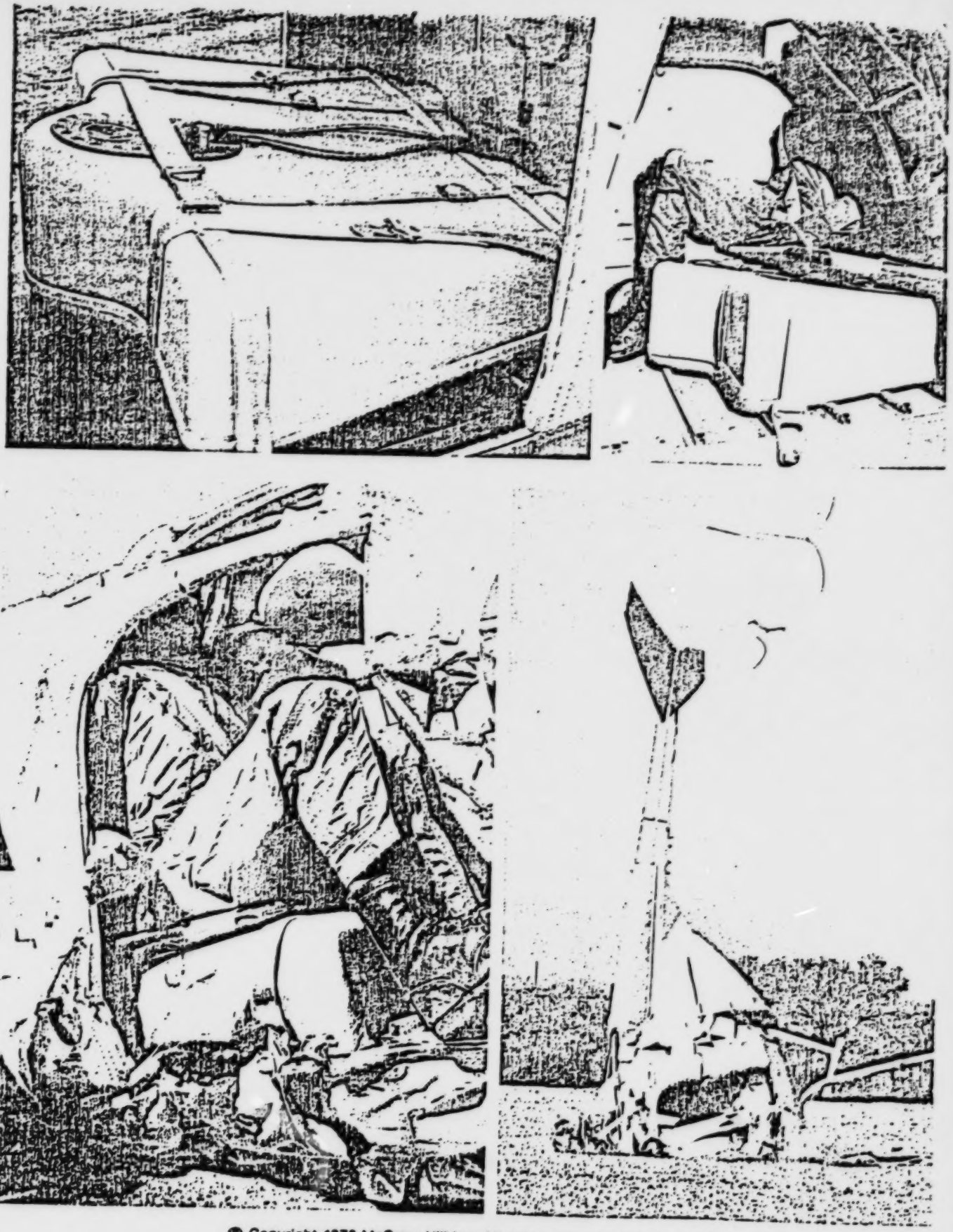




Hughes 500 Fuel Tank Crash-Tested

Crash tests with a 35-gal. auxiliary fuel tank for Hughes 500 helicopters was conducted recently at an abandoned military airfield near Phoenix, Ariz. Called the range extension fuel system, the 51-lb. (empty weight) tank was mounted inside a ballasted Hughes 500 airframe (facing page, top left) that previously had been slightly damaged in an accident and earlier testing. A safety testing dummy was strapped onto a rear passenger seat with shoulder and seat belts for the test (facing page, top right). The airframe was lifted to a height of 30 ft. by another Hughes 500 helicopter (above) and dropped to the ground with a forward velocity of about 35 mph. (below). The tank, marketed by Robertson Aviation, Inc., of Scottsdale, Ariz., remained strapped in position after the test and sustained no apparent ruptures or leaks (facing page, lower left). Fuel is contained in a fuel bladder enclosed by a crash container made of multi-ply nylon laminate that is designed to change shape under the stress of crash forces. The outer skin of the crash container, however, is a thin layer of fiberglass that cracks when the nylon laminate changes shape. The airframe then was lifted to a height of 65 ft. and dropped on its nose to simulate a crash that passengers would not be expected to survive (facing page, lower right). The tank also endured the 65-ft. drop without rupturing, leaking or breaking loose from its mounting straps. The fuel system includes self-sealing breakaway valves in the fuel and vent lines, a non-spill vent valve and high-G tank restraint harness. The tank, which weighs about 300 lb. when filled, was filled with red-dyed water for the test to make any possible leaks readily visible. The tank received FAA certification in January. The tanks are available as an option on new Hughes 500 helicopters.





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Hughes 500's

ALL MODELS

NEED MORE RANGE?
NEED MISSION FLEXIBILITY?

ROBERTSON CRASHWORTHY RANGE EXTENSION FUEL SYSTEM

WHY YOU SHOULD BUY OUR SYSTEM

It is the most operationally practical auxiliary fuel system known to exist in the world today.

IT CAN MAKE YOU MONEY

1. Increases your range and/or endurance by 50% or more.
2. Once installed, can be taken in or out in 5 minutes or less. This allows for quick conversion due to mission changes, and shorter ground times during inspections.
3. Can be filled in 3½ to 4 minutes, keeping ground time to a minimum.
4. Fleet operators install fixed plumbing in each helicopter, then move tank(s) between helicopters. Cost savings result because a tank is not needed for each helicopter.

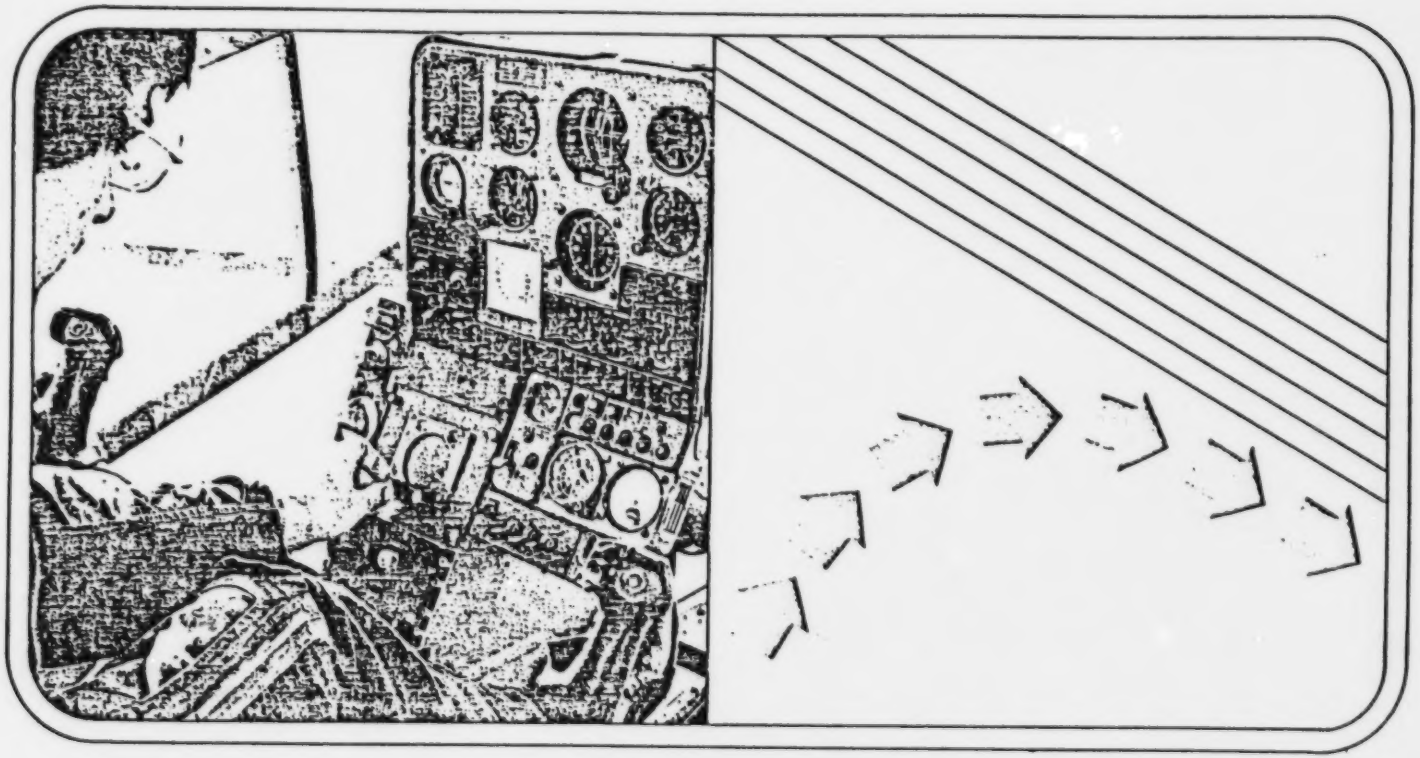
IT HAS PILOT APPEAL

1. Does not affect center of gravity.
2. Can be taken in and out with hands only — no tools required.
3. Gauge can be read by crew, re-fuelers, and cargo loaders without turning power on.
4. Has filler neck plug to prevent re-fueler from dumping fuel into helicopter when auxiliary tank has been removed.

IT HAS PASSENGER APPEAL

1. Smoking approved with tank installed.
2. Styled to complement helicopter appearance.
3. Allows passenger to sit on comfortable Hughes rear bench seat.
4. Allows storage behind the seat, as Hughes intended.
5. Designed to not spill fuel during accident.

BRITISH AEROSPACE
DYNAMICS GROUP



CABLE WARNING SYSTEM

For Helicopters and Light Aircraft

CABLE WARNING SYSTEM

Introduction

Pilots of helicopters and light aircraft are now able to detect and thus avoid high-voltage overhead power cables with the aid of a Cable Warning System developed by British Aerospace, Dynamics Group, Bracknell Division (formerly Sperry Gyroscope).

This compact, lightweight system, consisting of a sensor unit and a cockpit indicator, is designed for low-cost installation in many military and civilian fixed- or rotary-wing aircraft types. Operating in all weather conditions, by day or night, it improves the safety of low-flying operations by assisting the pilot in identifying this particular type of hazard.

On flight trials in various types of helicopters the system has demonstrated accuracy and reliability coupled with simplicity and effectiveness.

Operation

A pre-flight check is made by pressing the button on the indicator (marked PTT). The sensitivity control is then set, according to the environmental conditions; a high sensitivity setting (marked MAX) gives a long-range early warning for operation at high speed or in very bad weather. A low sensitivity setting (marked MIN) is for use at low speed or in clear conditions.

The detection range for the system can be up to 1600 metres (1 mile) depending on the sensitivity setting. Typically, detection of a power cable at a range of about 500 metres would give ten seconds' warning time to the pilot of an aircraft flying at 100 knots.

In-Flight Sequence

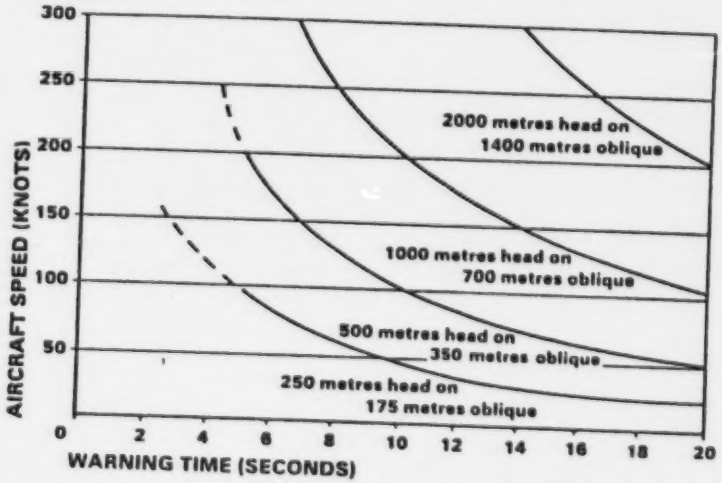
The presence of a power cable ahead is shown on the cockpit indicator by green coloured lights. As the power cable is approached an audio warning is sounded and the 'alert' display is shown. As the cable comes into range its direction, relative to the aircraft, is indicated by the green lights. When the cable is safely out of range the lights are extinguished and the display becomes blank.

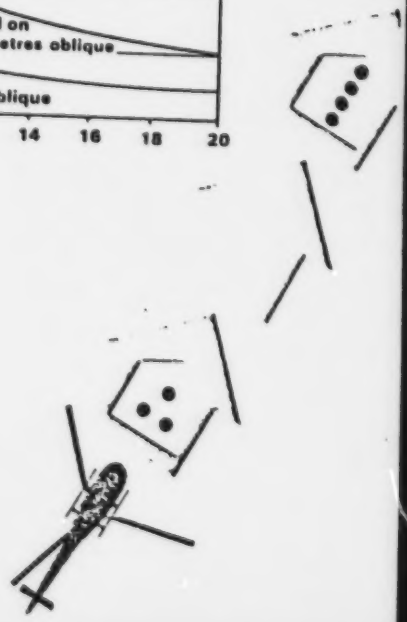
Application

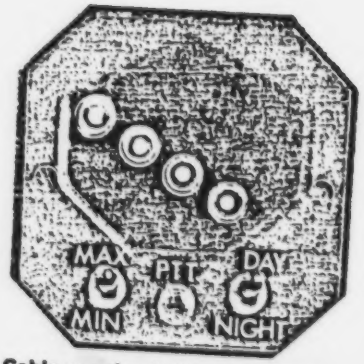
The system has applications in military aircraft engaged in reconnaissance, medical support, anti-armour action, tactical troop lift and battlefield support. Civilian helicopter applications include agriculture and forestry, police, inspection and V.I.P. transport.

Warning Conditions

Chart shows relationship between aircraft speed and warning time given relative to the range at which a cable is detected.







Cable warning indicator full size photo.

Cable to port

Cable ahead

Cable parallel

Cable to starboard

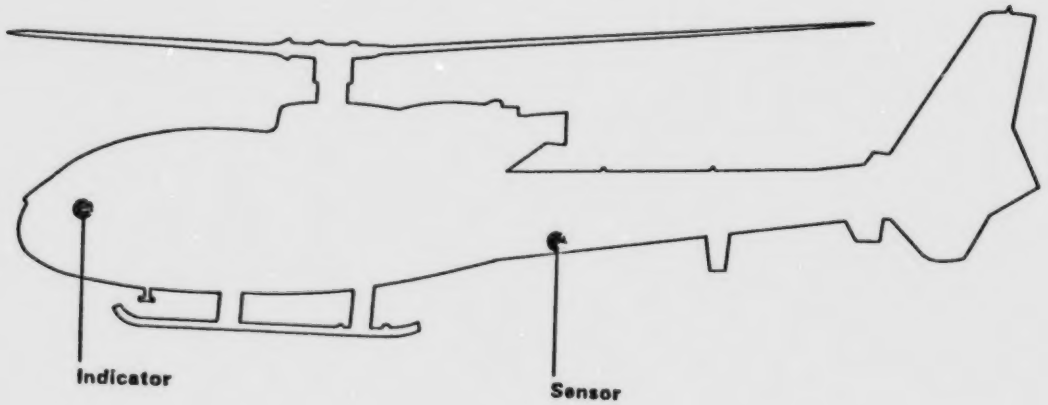
Cable below (display flashes).

Alert
Visual audio warning

Normal
When out of range of a power cable the display is in a 'safe' mode (blank).

Equipment Characteristics

	Cockpit Indicator	Sensor
Size	50mm × 50mm panel area (2in × 2in)	190mm × 150mm × 115mm 7.5in × 5.9in × 4.5in
Weight	0.6 kg (1.32lb)	4.0 kg (8.8lb)
Consumption	3 watts	4 watts
MTBF	8500 hours	6000 hours



BRITISH AEROSPACE
DYNAMICS GROUP

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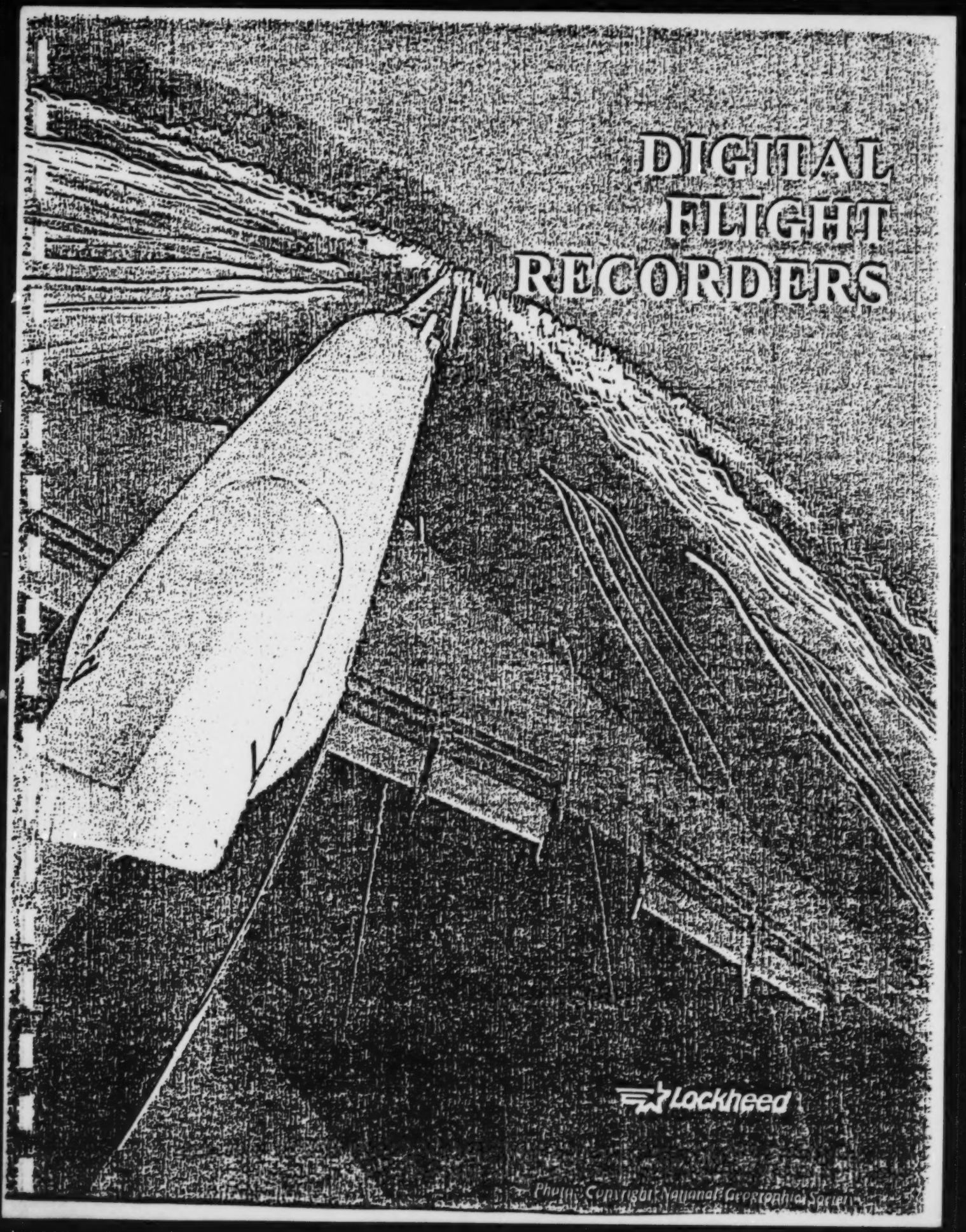
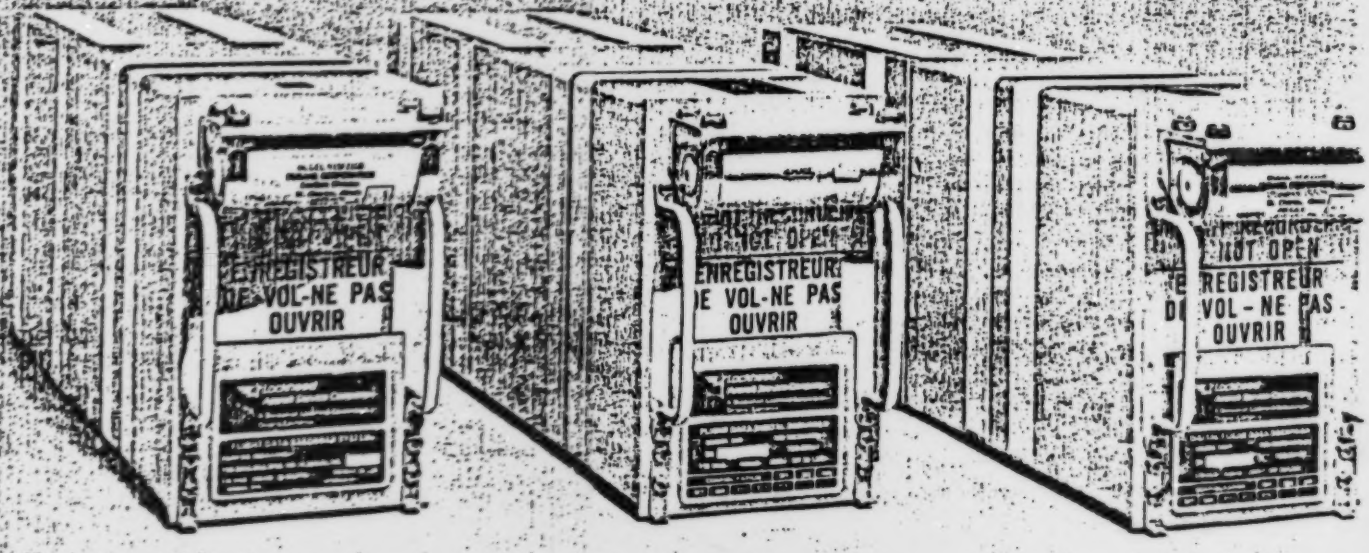
A - 5

FLIGHT DATA RECORDERS


DIGITAL
FLIGHT
RECORDERS
Lockheed
Photo: Copyright National Geographic Society

THE LOOK ALIKES FROM LOCKHEED

OUR FAMILY OF FLIGHT DATA RECORDERS INCLUDES A MODEL TO MEET YOUR REQUIREMENTS

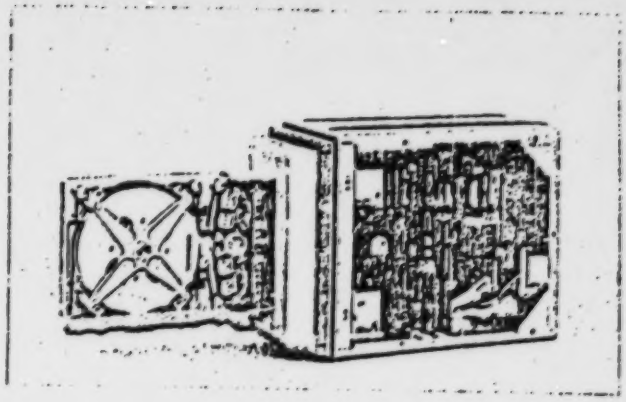


Model 209

Model 209F

Lockheed offers a variety of digital flight data recorders which are supported by a complete range of support equipment and services.

- Flight Data Recorders
- Maintenance Data Recorders
- Flight Line Support Equipment
- Maintenance Shop Support Equipment
- Data Readout Equipment
- Product Support
  - Spares
  - Overhaul and Repair
  - Training
  - Data Readout
  - Technical Assistance
- Recorder System Design and Installation



PHYSICAL CHARACTERISTICS

SIZE:	1/2 ATR long Height: 7.6 in. (19.30 cm) Width: 4.9 in. (12.45 cm) Length: 19.5 in. (49.53 cm)
WEIGHT:	23 pounds (10.5 kg)
MOUNTING:	1/2 ATR long rack on isolators
OPERATING TEMPERATURE:	-55 Deg. C. to +70 Deg. C.
MOTOR:	AC induction-type, operated at 1/60 rated speed during recording for long motor life.
DRIVE SYSTEM:	V-belt power transfer for long life with no alignment problems.
SPEED CONTROL:	Unique electronic speed control, using an optically-coupled tachometer disc for minimum wow and flutter and long operating life.
MICROPROCESSOR BITE:	Provides validity and recoverability check of recorded data.

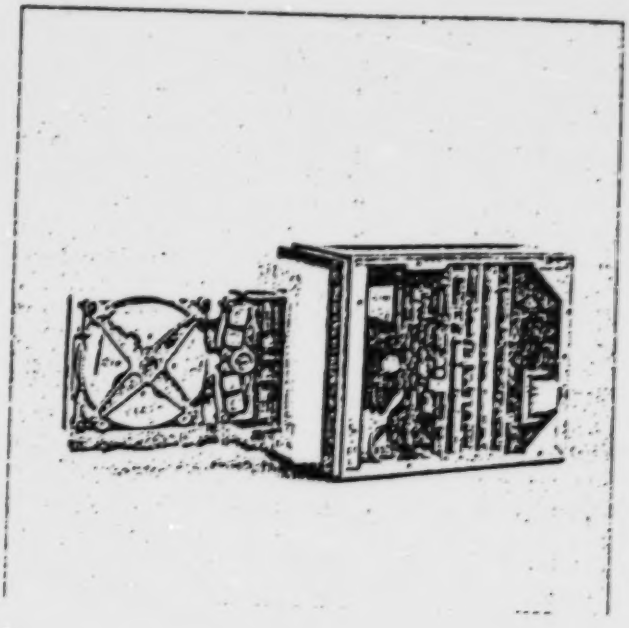
OPERATING CHARACTERISTICS

POWER:	115 VAC, 400 Hz; 20 watts maximum for record, 40 watts maximum for high-speed playback.
INPUT SIGNAL:	Harvard biphase, 768 bits per second
TAPE SPEED:	0.37 inch per second
BIT PACKING DENSITY:	2076 bits per inch at 64 words (12 bits each) per second
RECORD DURATION:	25 hours minimum, continuously updated
HIGH-SPEED PLAYBACK TIME:	Less than 16 minutes for total record
REAR CONNECTOR OUTPUTS:	Track number and direction codes, power for test sets (+12V, -12V), low-speed data monitor output for verification of recorded data.
REAR CONNECTOR INPUTS:	High-speed playback and high-speed track advance commands, track switching command, record inhibit command
DFDR CONDITION OUTPUTS:	BITE and status (maintenance and mandatory) outputs at rear connector in accordance with ARINC 573.

The Model 209F, Model 229, and Model 319 recorders embody the same design concepts with many of the components and subassemblies being interchangeable. These recorders share a common tape deck, which is easily removed for service and simplifies spares logistics. All of these recorders are available with underwater locator beacon.

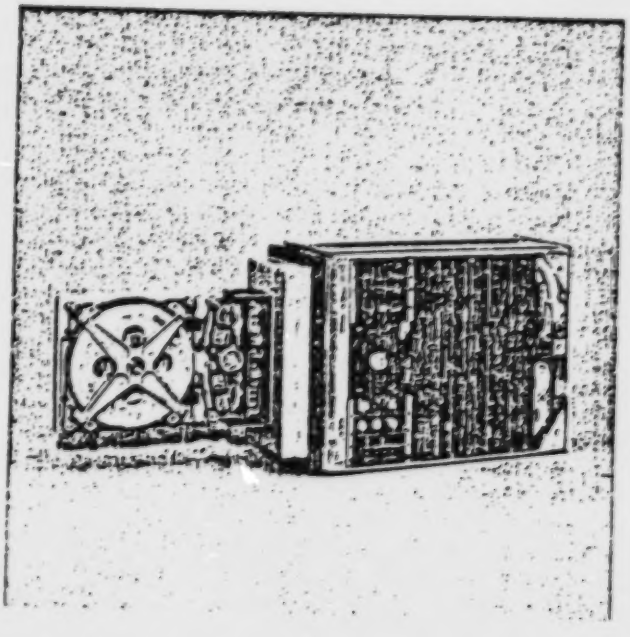
Model 229 FDDR

The Model 229 flight data digital recorder (FDDR) was developed expressly to replace the FAA-mandated ARINC 542 metal foil oscillographic recorder system. The unit will record a minimum of 11 input parameters. The Model 229 replaces existing foil recorder installations, and shares the high speed playback, high reliability, and crash protection of the Model 209F DFDR and the Model 319 FDRS.



Model 319 FDRS

The Model 319 flight data recorder system (FDRS) satisfies the requirements of ARINC 573 and FAR 121 in aircraft where space or weight are important considerations. The FDRS combines the capability of a flight data acquisition unit (FDAU), which is normally mounted in an avionics bay, with the features of a digital flight data recorder normally mounted in the tail of the aircraft. This composite crash-protected FDRS is installed in the tail of the aircraft and shares the high-speed playback, high reliability, and crash protection of the Model 209F DFDR and Model 229 FDDR. An optional Model 329 flight data entry panel (FDEP) is available to enter documentary data (flight number, leg, weight, etc.). **The FDRS will accommodate 73 analog and 30 discrete signals of the following types: Synchros, DC and AC ratio, high and low level DC, potentiometer, variable resistance, and frequency. The signal sample rate is programmable from one sample in four seconds to eight samples in one second. Accuracies meet or exceed ARINC 573.**



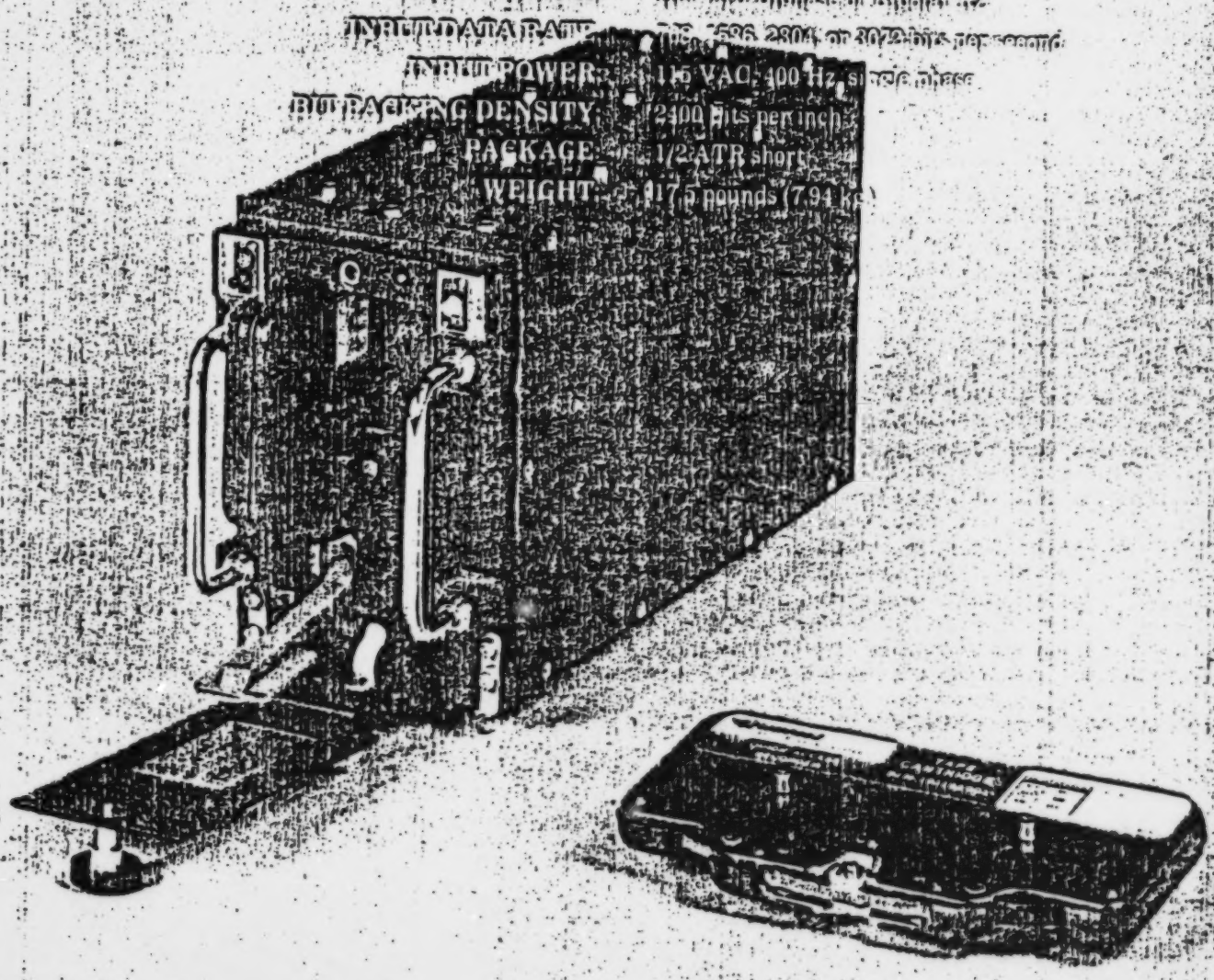
MODEL 280 QUICK ACCESS RECORDER

The Model 280 quick access recorder (QAR) was primarily designed for recording and storing aircraft maintenance data. Total data capacity is in excess of 50 hours (more than 140 million bits). The Model 280 can be easily adapted for use with L-382 or 4 high data acquisition units (HDAU) and can handle two HDAU's without the use of a data management unit.

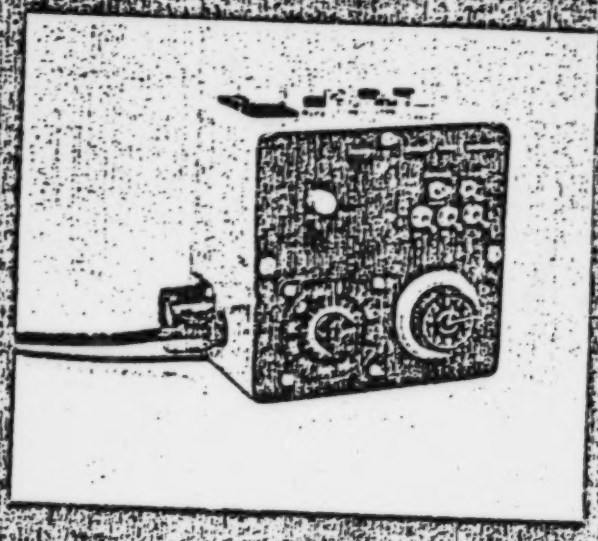
The Model 280 QAR uses a commercially-proven cartridge that has been modified for the demanding airborne environment. The cassette is made of rugged formed aluminum and uses two flanged reels for tape storage.

- Designed to ARINC 600 Specifications
- Cartridge loaded for quick access to data
- Playback data at its times record speed
- More than 50 hours of continuous recording
- Automatic multiplexing of signals from two HDAU's
- No data management unit required

INPUT SIGNAL	Harvard Biphase or Bipolar RZ
INPUT DATA RATE	The 5586, 2804, or 3072 bits per second
INPUT POWER	115 VAC, 400 Hz, single phase
RECORDING DENSITY	2400 bits per inch
PACKAGE	1/2 ATR short
WEIGHT	17.5 pounds (7.94 kg)

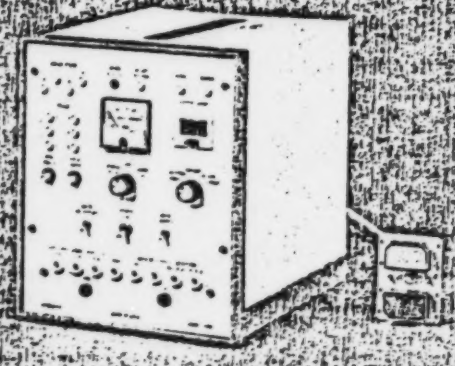


MAINTENANCE SHOP SUPPORT EQUIPMENT



MODEL 232 FDDR CONTROL/SIGNAL SIMULATOR

The Model 232 FDDR Control Signal Simulator is 5 inches (12.7 cm) high, 5 inches (12.7 cm) wide, 6 inches (15.2 cm) deep and weighs 2.5 pounds (1.1 kg). This unit uses 115 VAC 400 Hz power. The Model 232 interfaces with the Model 229 FDDR through a single connector. It will also interface with the Model 221A DFDR Tester, Model 320 Flight Line Test Set and Model 235 Copy Recorder. The Model 232 provides fixed and variable simulations of aircraft signals necessary for testing and fault isolation of the Model 229 FDDR.

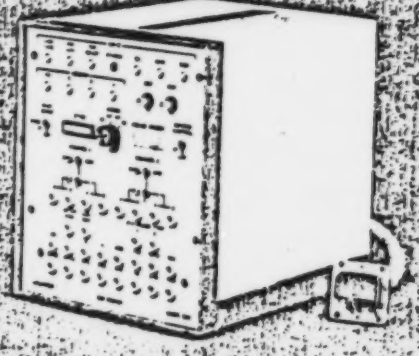


MODEL 221A DFDR TESTER

The Model 221A DFDR Tester interfaces with the Lockheed-Ontario digital flight recorders and provides the following functions:

1. Tests for recorded data.
2. Tests error count at high speed.
3. Tests for continuous synchronization at high speed.
4. Tests BITE circuits.
5. Used for fault isolation of recorder malfunctions.

Both the Model 221A and Model 283 require 115 VAC, 400 Hz, single phase power. They are 10 inches (25.4 cm) high, 8.37 inches (21.26 cm) wide, 11 inches (27.94 cm) deep and weigh approximately 12 pounds (5.4 kg).



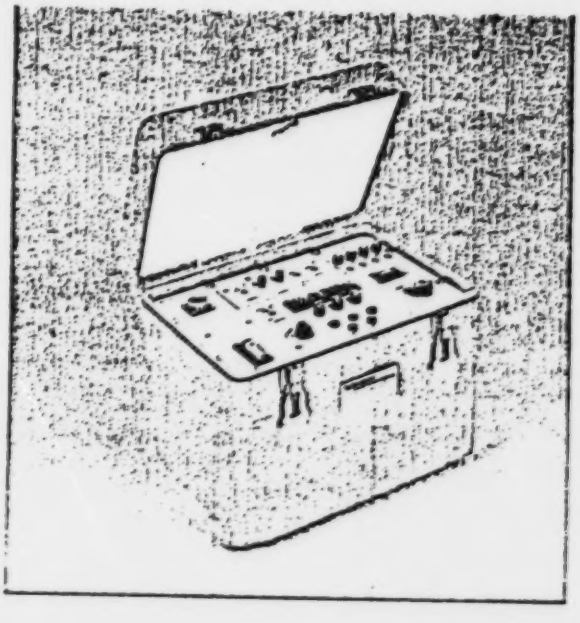
MODEL 283 QAR TESTER

The Model 283 QAR Tester interfaces with the Model 280 QAR. It generates simulated inputs to the QAR under test and provides test jacks for observation of both input and QAR internal signals.

FLIGHT LINE SUPPORT EQUIPMENT

MODEL 235 COPY RECORDER

The Model 235 copy recorder is 21 inches (53.3 cm) long, 14 inches (35.5 cm) wide, 6.75 inches (17.1 cm) deep and weighs approximately 20 pounds (9.1 kg). This unit interconnects to the recorder system via a test connector in the aircraft wiring and uses 115 VAC, 400 Hz, single phase aircraft power, 100 watts maximum. The entire process of copying 25 hours of flight data from a recorder is completed in less than 16 minutes without disturbing the data on the recorder.



MODEL 320 FLIGHT LINE TEST SET (FLTS)

The Model 320 FLTS is 11.5 inches (29.2 cm) high, 13.25 inches (33.8 cm) wide, 9.2 inches (23.2 cm) deep and weighs 16.5 pounds (7.5 kg). This unit interconnects to the recorder system via a test connector in the aircraft wiring and uses 115 VAC, 400 Hz, single phase aircraft power, 50 watts maximum. The FLTS may be used for calibration of a recorder system or to perform fault isolation of system components.

In addition to equipment described in this brochure Lockheed also offers other flight recorder products including data playback equipment and additional services including aircraft modification for new or retrofit installation of complete flight recorder systems.

FOR MORE INFORMATION, CONTACT:
DIRECTOR OF MARKETING

Lockheed Aircraft Service Company
P.O. Box 33
Ontario, California 91762-8033 USA
(714) 988-2193
Telex: 182974 LOCHEED-ONTO
TWX: 910-581-341

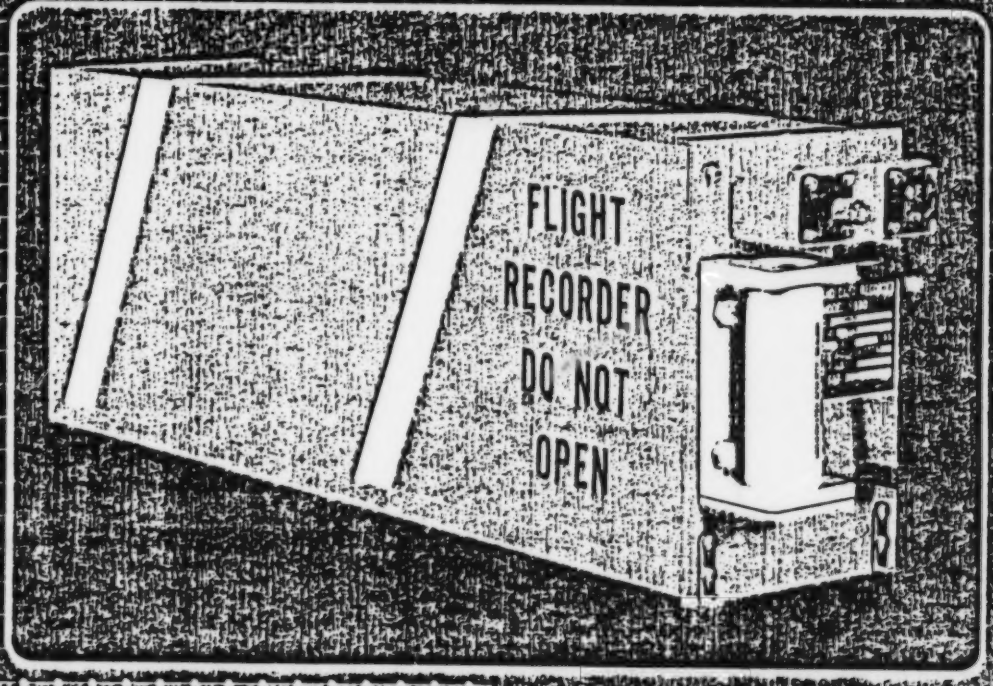
COMMON FEATURES

- High mean time between failure (MTBF)
- 5,000 hour mean time between overhaul (MTBO)
- Microprocessor control and built-in test circuitry
- Built-in microprocessor data verification circuitry
- Nondestructive high-speed playback in place in less than 15 minutes
- Tungum housing and dry thermal insulation for data protection
- Low weight and power consumption
- Proven mylar recording medium, tape deck and drive system

So what is the difference?

- The Model 209 is a Digital Flight Data Recorder (FDR) which is combined with a separate Flight Data Acquisition Unit (FDAU) to meet requirements of an ARINC 573 or ARINC 717 recorder system.
- The Model 209 is a self-contained Flight Data Digital Recorder (FDR) to replace ARINC 542 foil recorders.
- The Model 210 is also a self-contained Flight Data Recorder System (FDRS) which meets requirements for an ARINC 573 recorder system.

Fairchild Digital Flight Recorder



- Time-proven Tape Transport Mechanism
- State-of-the-art microprocessor circuitry
- Low initial and operating costs
- Low power consumption
- Readout (Ieat) interfaces with mini-computers
- Expandable to meet regulatory requirements

FAIRCHILD WESTON SYSTEMS INC.

Fairchild Weston Schlumberger

FAIRCHILD DIGITAL FLIGHT RECORDER

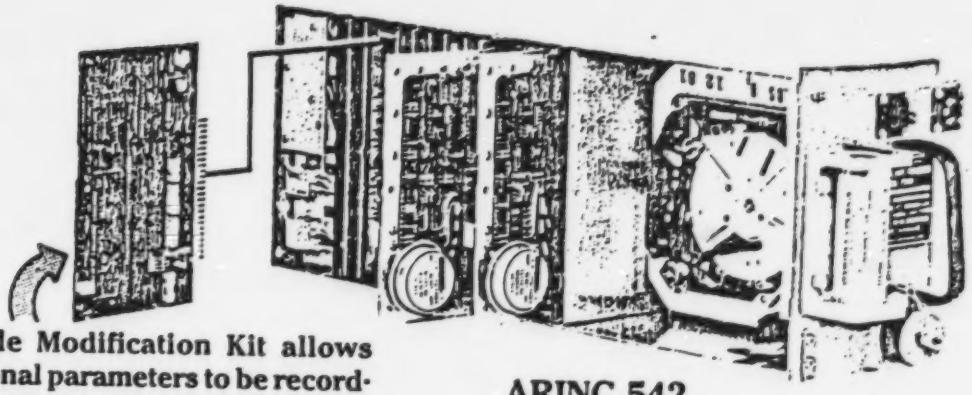
MODEL F800

The Fairchild Model F800 meets FAA TSO-C51a requirements and is designed to operate as an ARINC 573/717 Recorder or as an ARINC 542 replacement. The Recorder also functions as a Combination Recorder which allows interchangeability with Airline Fleets using both ARINC configurations.

The new Fairchild Digital Flight Recorder combines state of the art electronics using Microprocessor technology with a time proven crash and fire protected tape transport derived from the more than 15,000 Fairchild Cockpit Voice Recorders in airline service. The Recorder is designed to interface with modern mini or business type computers for data readout and automatic testing without need for interfacing and programming with large computer centers.

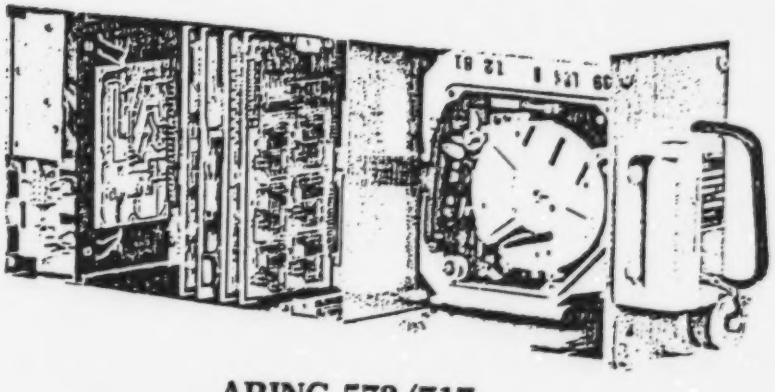
- Time-proven Tape Transport mechanism to record data and protect tape from fire and crush. Excellent survivability proven by NTSB reports.*
- Microprocessor circuitry provides exceptional flexibility and reliability.
- 8000 hour MTBF.
- Front Panel ATE Connector for data retrieval and testing on aircraft or bench.
- Complete self-test and verification of tape recording and tape movement.
- Precision Head/Bridge Assembly for easy replacement and head alignment.
- Many parts interchangeable with Fairchild CVR for low spares supply requirements.
- Lower initial and operating costs than metal foil flight recorders.
- Uses high quality mylar tape for reliability and long life characteristics.
- Records on continuous loop with no reversals.
- Automatic track switching over 6 tracks assures continuous recording of data.
- All data readout directly in engineering values. No binary, octal or hexidecimal conversion required.
- Tape transport module is completely self-contained, replaceable unit.
- All Printed Circuit cards are plug-in replaceable units.
- Power consumption max 24 watts depending on configuration.
- Continuous data readback can be accomplished while recording.
- Previous data can be accessed on the 5 other tracks for readout or copy during recording.
- Uses two 6 track heads - one for write and one for read. No separate erase heads - no interlaced head tracks.
- Low head wear due to constant tape speed.
- Single capstan drive for simplicity.

*National Transportation Safety Board Records of Survivability and Recoverability of Data from current CVR's over period of 10 years.



Upgrade Modification Kit allows additional parameters to be recorded. This meets or exceeds the latest ARINC 542A specification.

ARINC 542
OR
COMBINATION
ARINC 542/ARINC 573/717
CONFIGURATION



ARINC 573/717
CONFIGURATION

FLEET COMPATABILITY

Designed for 25 hours of digital data recording, the F800 in its simplest version functions as an ARINC 573/717 Digital Flight Recorder.

In the ARINC 542 configuration the DFR is completely interchangeable with existing ARINC 542 FDR (metal foil) recorders and offers considerable cost savings over these older units.

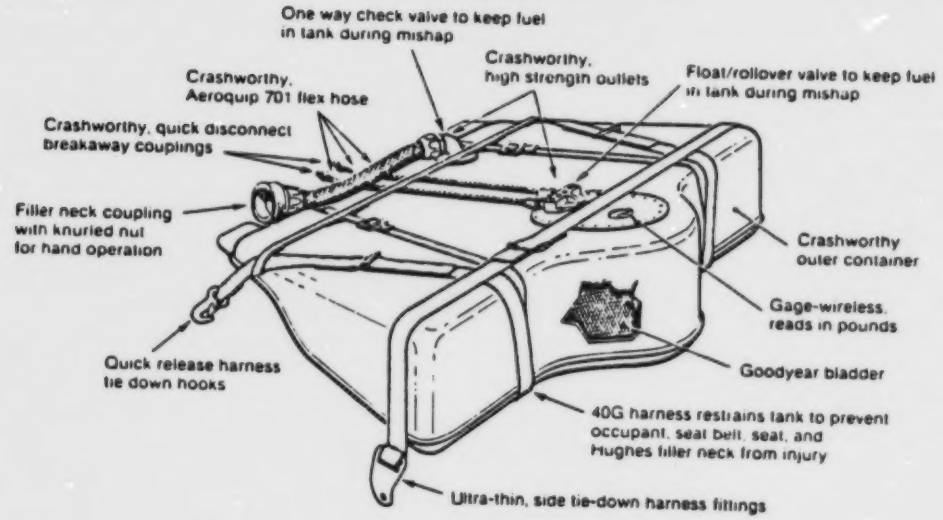
The ARINC 542 configuration can be modified to add additional parameters in Synchro, DC voltages/ratios or frequencies, to meet FAA regulations and the new ARINC 542A characteristic.

The Fairchild DFR is also available in a combination ARINC 573/542 configuration to meet all airline requirements.

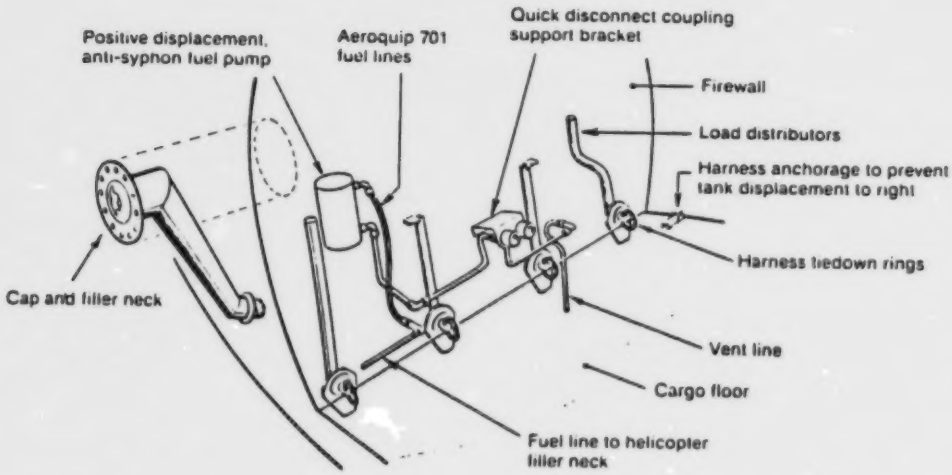
— DATA SHEET —

Tank Identification	HA-010C
Helicopter	All Models Hughes 500
Capacity	38.5 U.S. Gallons
Location	Under rear bench seat
Weight	56 lbs. empty - 306 lbs. full

TANK AND HARNESS


One way check valve to keep fuel in tank during mishap
Crashworthy, high strength outlets
Float/rollover valve to keep fuel in tank during mishap
Crashworthy, Aeroquip 701 flex hose
Crashworthy, quick disconnect breakaway couplings
Filler neck coupling with knurled nut for hand operation
Crashworthy outer container
Gage-wireless, reads in pounds
Quick release harness tie down hooks
Goodyear bladder
40G harness restrains tank to prevent occupant, seat belt, seat, and Hughes filler neck from injury
Ultra-thin, side tie-down harness fittings

FIXED PLUMBING



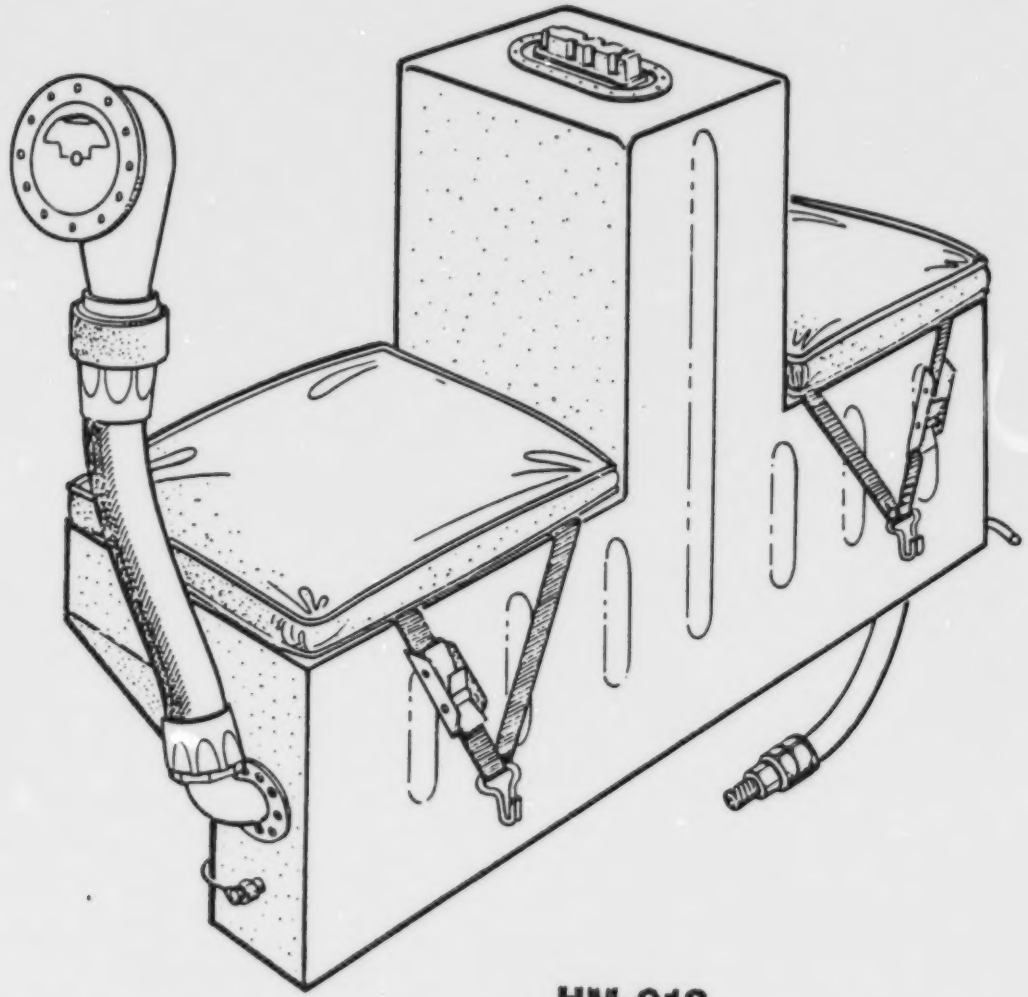
CRASH SAFETY This CRASHWORTHY auxiliary fuel system has been designed and tested to provide the highest degree of fuel spillage prevention available today! The fuel is carried in a Goodyear bladder installed in our special, flexible, non-fiberglass CRASHWORTHY outer container.

AVAILABILITY The tanks can be purchased through Hughes Service Centers, the Hughes Factory, or they can be ordered directly from us.

ROBERTSON
AVIATION, INC.
P.O. BOX 968, TEMPE, ARIZONA 85281 • PHONE (602) 967-5185

Military Helicopter Auxiliary Fuel Systems

by ROBERTSON Aviation, Inc., the largest producer of auxiliary fuel systems for the MD 500/530 MG series helicopters. Built to U.S. government exacting standards.



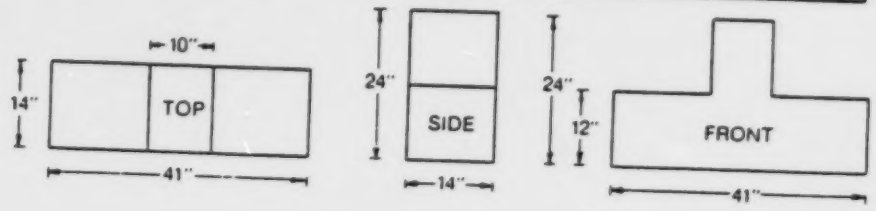
HM-012
Auxiliary Fuel System
...Rugged where rugged counts...

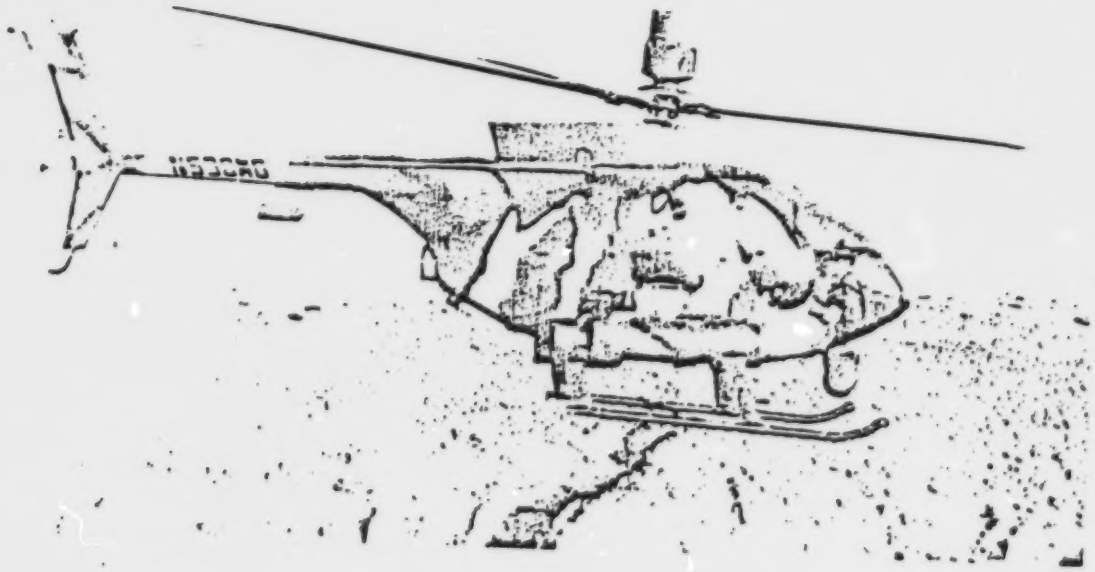
- Increases your range and/or endurance by 40% or more.
- Can be taken in and out in 5 minutes or less.
- Can be filled in 1 to 2 minutes, keeping ground time to a minimum.
- Gravity fuel transfer—no pumps or electricity required.
- Provides seating for two occupants.
- Minimum affect on center of gravity.
- Can be taken in and out with hands only—no tools required.
- Designed to provide extra cargo space.
- Designed for rugged use in the field.

Why the MD 500/530 MG helicopters use the ROBERTSON auxiliary fuel systems. ROBERTSON Aviation has more experience with, and fuel systems for, the MD 500/530 family of helicopters than anyone in the world. These systems are designed for rugged use in the field. They are designed, tested, and manufactured by pilot/engineers for the working pilot. Careful attention to operational detail and appearance is demonstrated throughout each design. The fuel systems can be taken in and out of the helicopter quickly with bare-hands or minimum tools, and most can be filled from outside the helicopter. Smoking is permitted with tanks installed.

DATA SHEET

Tank Identification	HM-012
Helicopter	All models MD 500/530
Capacity	28 U.S. Gallons
Location	Aft. Cargo Compartment
Seating Capacity	2
Weight	38 lbs. empty – 235 lbs. full





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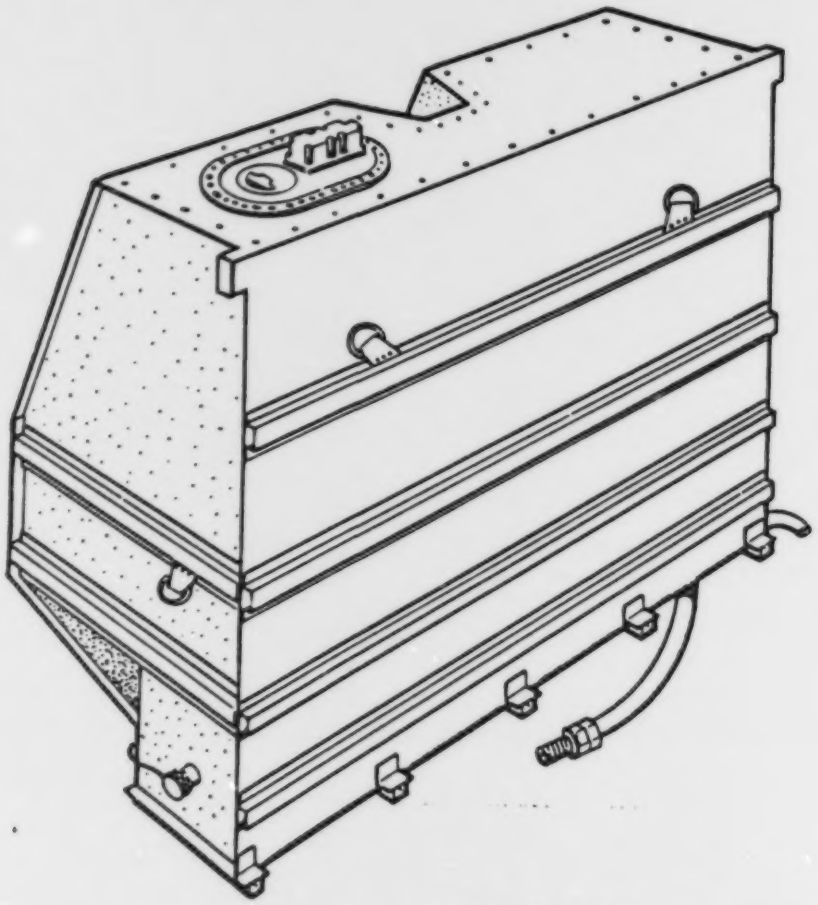


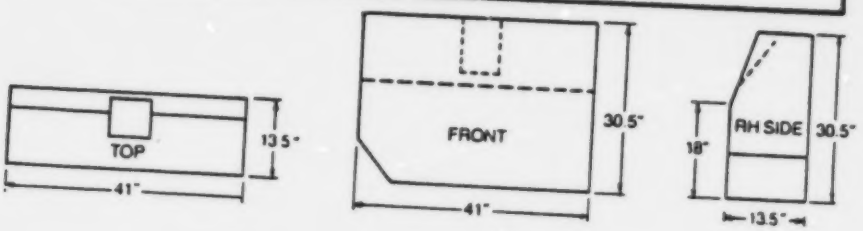
HM-016
Auxiliary Fuel System
...Rugged where rugged counts...

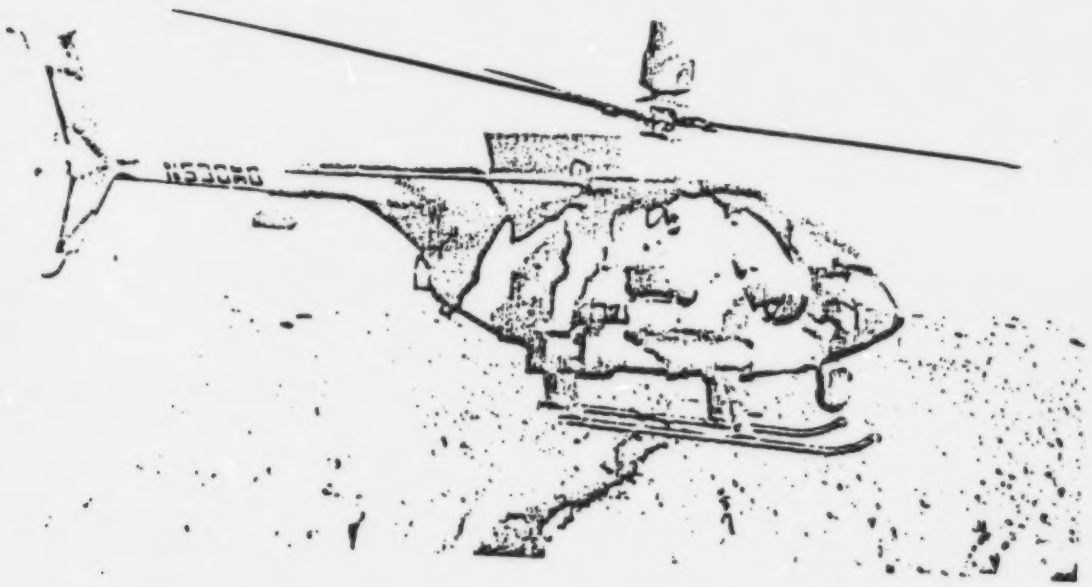
- Increases your range and/or endurance by 80% or more.
- Can be taken in and out in 5 minutes or less.
- Can be filled in 1 to 3 minutes, keeping ground time to a minimum.
- Gravity fuel transfer—no pumps or electricity required.
- Minimum affect on center of gravity.
- Can be taken in and out with hands only—no tools required.
- Designed to provide extra cargo space.
- Designed for rugged use in the field.

Why the MD 500/530 MG helicopters use the ROBERTSON auxiliary fuel systems. ROBERTSON Aviation has more experience with, and fuel systems for, the MD 500/530 family of helicopters than anyone in the world. These systems are designed for rugged use in the field. They are designed, tested, and manufactured by pilot/engineers for the working pilot. Careful attention to operational detail and appearance is demonstrated throughout each design. The fuel systems can be taken in and out of the helicopter quickly with bare-hands or minimum tools, and most can be filled from outside the helicopter. Smoking is permitted with tanks installed.

DATA SHEET

Tank Identification	HM-016
Helicopter	All models MD 500/530
Capacity	63.5 U.S. Gallons
Location	Aft. Cargo Compartment
Weight	60 lbs. empty – 466 lbs. full
Options	Gauge and Flow Sensor





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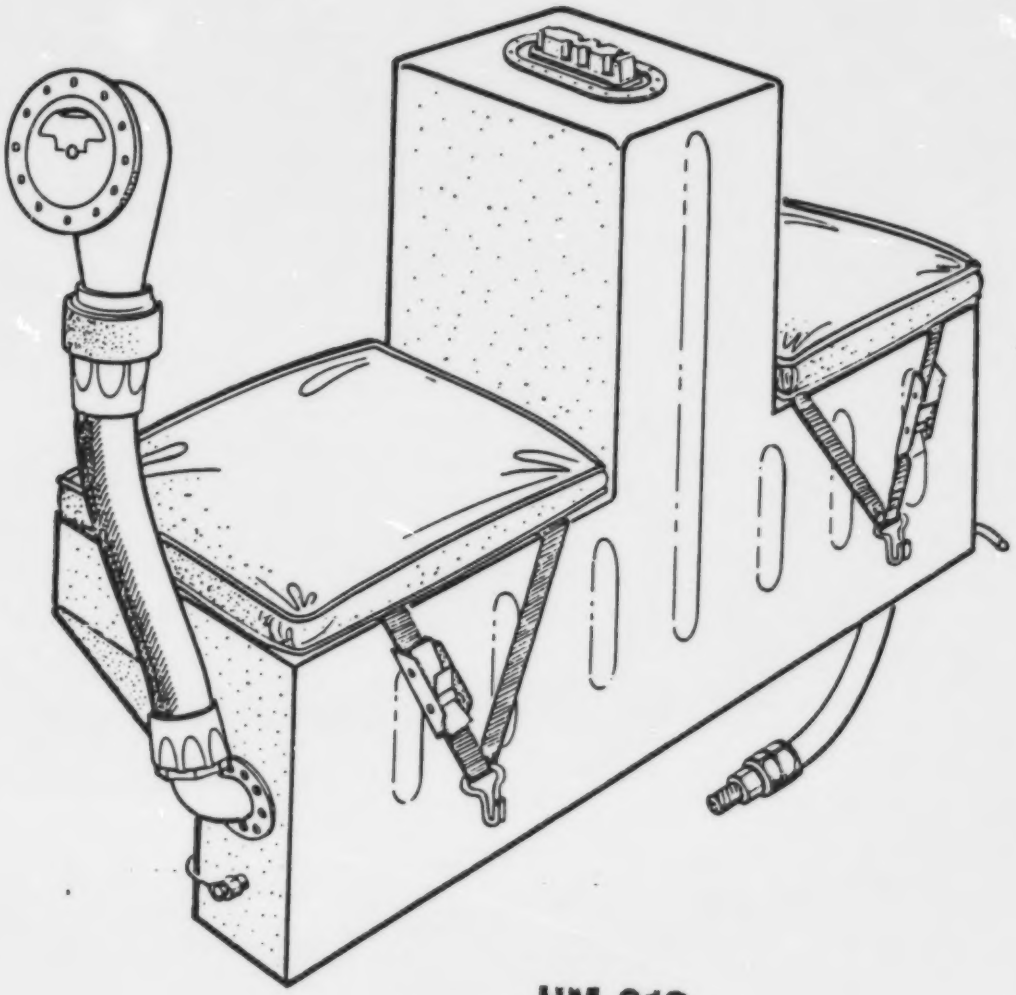
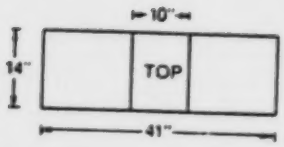


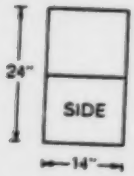
HM-012
Auxiliary Fuel System
...Rugged where rugged counts...

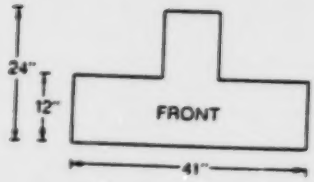
- Increases your range and/or endurance by 40% or more.
- Can be taken in and out in 5 minutes or less.
- Can be filled in 1 to 2 minutes, keeping ground time to a minimum.
- Gravity fuel transfer—no pumps or electricity required.
- Provides seating for two occupants.
- Minimum affect on center of gravity.
- Can be taken in and out with hands only—no tools required.
- Designed to provide extra cargo space.
- Designed for rugged use in the field.

— DATA SHEET —

Tank Identification HA-012
Helicopter..... All Models Hughes 500's
Capacity ..... 30 U.S. Gallons
Location ..... Aft Cargo Compartment
Weight..... 38 lbs. empty - 235 lbs. full







BASIC FUEL SYSTEM INCLUDES:

Riveted Aluminum Outer Container
Goodyear Bladder
2 Seat Cushions
30 (U.S.) Gallon Capacity
5-Minute In/Out Time
30 Lb. Weight (Approx.)
Rollover Vent Valve
Non Spill Filler Valve

CONFIGURATION OPTIONS

TANK I.D.	BASIC SYSTEM	GAUGE	SIDE FILL	GRAVITY TRANSFER	FUEL PUMPS	INSIDE FILLER	USER TIE-DOWN	RAI TIE-DOWN	FLOW SENSOR
A	X	...	...	...	X	X	X	...	...
B	X	...	...	...	X	X	X	...	X
C	X	...	...	...	X	X	...	X	...
D	X	X	...	...	X	X	X	...	...
E	X	X	...	...	X	X	...	X	...
F	X	...	X	...	X	...	X	...	...
F-1	X	...	X	...	X	...	X	...	X
G	X	...	X	...	X	...	...	X	...
H	X	X	X	...	X	...	X	...	...
I	X	X	X	...	X	...	...	X	...
J	X	...	X	X	...	...	X	...	...
K	X	...	X	X	...	...	...	X	...
L	X	X	X	X	...	...	X	...	...
M	X	X	X	X	...	...	...	X	...

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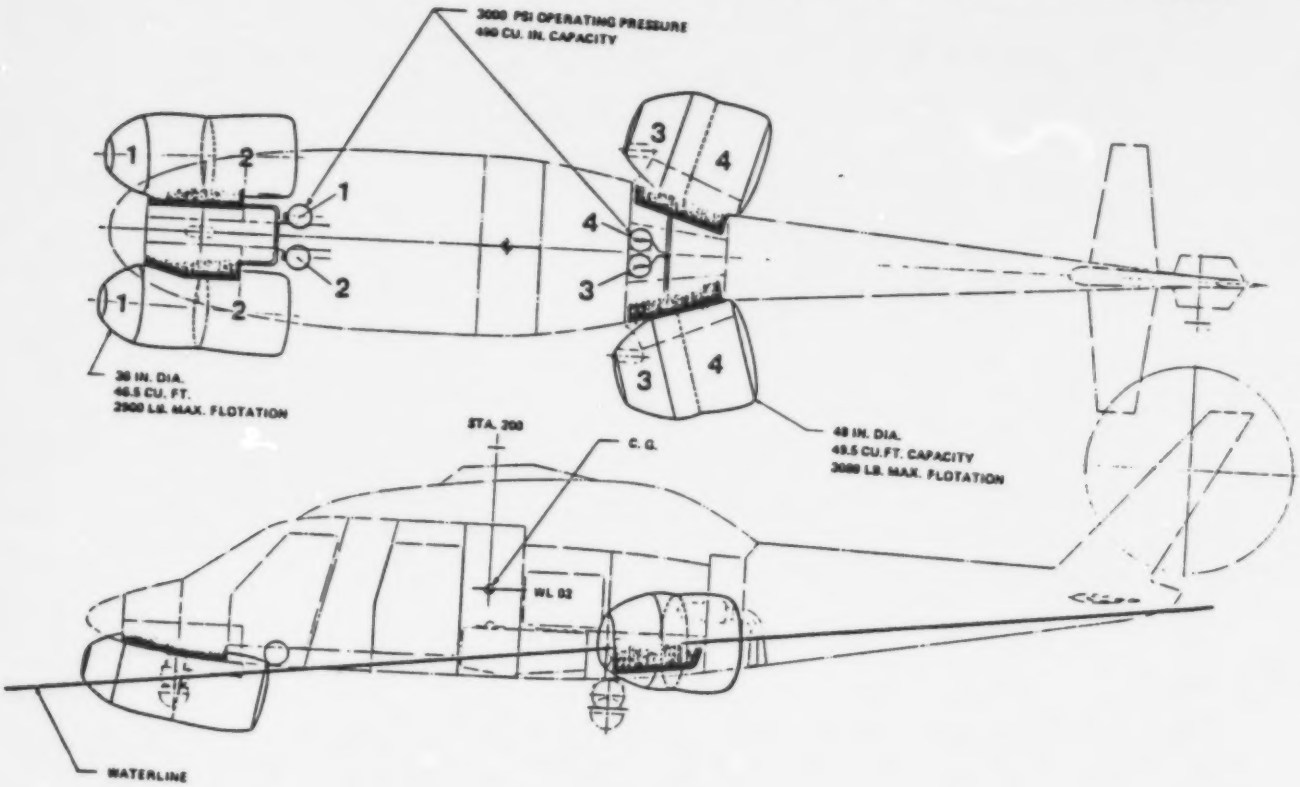
A - 3

OVERWATER OPERATIONAL SAFETY SYSTEMS

UNITED TECHNOLOGIES SIKORSKY AIRCRAFT

No. 761-202-1

EMERGENCY FLOTATION SYSTEM



- Completely enclosed within fuselage
- Fully redundant inflation and compartmentation
- 153% buoyancy provided (10500 Lb. G.W.)
- Light weight - 114 Lbs. - Total system
- Designed for 33 Kts. water impact
- 75 Kt. maximum airspeed for actuation or flight with bags inflated
- Helium or nitrogen serviceable
- FAA and CAA certified

See reverse side

Published by Sikorsky Aircraft, Connecticut 06601 USA (203) 386-7600

DITCHING (FLOTATION SYSTEM)

The optional emergency flotation system is designed only for emergency landing on water. The system may be expected to keep the helicopter upright long enough to permit passengers and crew to exit to life rafts or rescue boats. A subsequent takeoff or long term towing should not be attempted.

When it appears that ditching is likely, consideration must be given to such factors as wind direction and velocity, sea state conditions, and aircraft power available for ditching. The maximum permissible water entry conditions are 33 knots water speed at 300 feet per minute rate of descent in a calm sea. Optimum ditching conditions would occur in a calm sea state with the forward speed of the helicopter reduced to as near zero as possible, and with little or no lateral drift component. Minimum touchdown forces will be achieved when touchdown is made on the crest or back of a wave with a minimum rate of descent. Greatly increased touchdown forces will be experienced if the landing is made on the front or rising face of a wave. Every effort should be made to land the helicopter with as little sideward drift as possible as the roll rate after touchdown increases sharply with any increase in lateral motion. Ditching with power available (such as when fuel starvation is imminent, or a loss of transmission oil pressure dictates such action) will greatly increase controllability, reduce touchdown forces, and assist in preventing the helicopter from rolling after impact. Power off ditching (autorotation) should be avoided if possible. With sufficient power available to fully control the aircraft descent rate, sideward drift and forward speed to near zero values, successful ditchings may be accomplished in sea states up to and including Sea State 4 (wave height 6.5 feet, wave length to height ratio - 1 to 10) depending on wind conditions.

All possible control available from the rotor system should be used to prevent rolling after impact. Consideration should be given to extended power on water taxi, if wave conditions make rotor to water contact improbable. Power-on water taxi will greatly increase the roll stability of the aircraft and will allow yaw and heading control. The floats may be inflated at any time during the ditching procedure (below 75 KIAS). Allow sufficient time for full inflation before water contact. Float inflation time is within 10 seconds.

The following general ditching techniques are recommended as the best for a successful controlled emergency water landing:

- Activate the inflation system in a hover if sufficient power is available to permit a hover.
- Reduce forward speed to as near zero as possible.
- Reduce lateral drift component to a minimum.
- Avoid rising faces of large waves.
- Reduce rate of descent to minimum at touchdown.
- Fuselage angle at impact should be between 0° and 10° nose up.
- Use all control available from the rotor system to prevent the helicopter from pitching or rolling after touchdown.
- The pilot should endeavor to touchdown, heading into wind, as near the crest of a wave as possible to minimize the impact vertical velocity.
- If the helicopter is towed, it should be towed at a slow rate of speed.

DITCHING PROCEDURES

1. Flotation system test switch - Check NORM.
2. Landing gear - DOWN.

NOTE

If the landing gear cannot be extended for any reason, the floats can be deployed with the gear retracted.

CAUTION

Operation of the landing gear during or after float inflation may result in damage to the floats and partial loss of flotation capability.

3. Float arming switch - ARMED.
4. Press the cyclic stick float inflation switch. Allow sufficient time for full inflation prior to water contact.

NOTE

Float inflation time is 10 seconds.

5. Notify all occupants to prepare for emergency water landing.

NOTE

Cabin occupants should fasten their safety belts and remain in their seats with their arms braced against their knees until water contact is made.

NOTE

If time and conditions permit, consider opening and locking r. h. sliding door if modified by Kit P/N 76076-20015-011.

6. Transmit distress message.
7. Check life vests for security and lock shoulder harness.
8. Hold the helicopter level as possible, contact the water with minimum forward speed and rate of descent.
9. Water and aircraft conditions permitting-consider extended water taxi.

SINGLE-ENGINE LANDING IN THE WATER (FLOTATION GEAR INFLATED)

NOTE

The following procedures are recommended if single engine flight to a safe landing area is not possible.

1. Establish normal approach so as to arrive at approximately 100 feet above touchdown point at 50 KIAS at a rate of descent of no more than 500 FPM.
2. Decelerate to pass 50 feet at 40 KIAS and increase power to reduce rate of descent to a maximum of 300 FPM.
3. Continue deceleration to running touchdown at or above translational lift.
4. Follow procedures 9 and 10 above.

AUTOROTATIVE LANDING TO THE WATER

1. Establish autorotative glide.
2. Inflate floats using Ditching procedures above.
3. At about 50 to 75 feet, execute a partial flare to about 20° nose up by moving cyclic stick back with no change in collective pitch. This will reduce airspeed and rate of descent and will cause an increase in rotor rpm.
4. Gradually increase collective pitch and apply forward cyclic as the helicopter settles and until water contact is made.
5. Maximum desired water contact speed is 30 knots. Desired nose attitude is +10° or less.
6. Immediately after water contact, decrease collective pitch smoothly and slowly.
7. Water and aircraft conditions permitting, consider remaining in aircraft until rescued.
8. Follow Item 10 and the warning under Ditching Procedures.

DITCHING (WITHOUT FLOTATION SYSTEM)

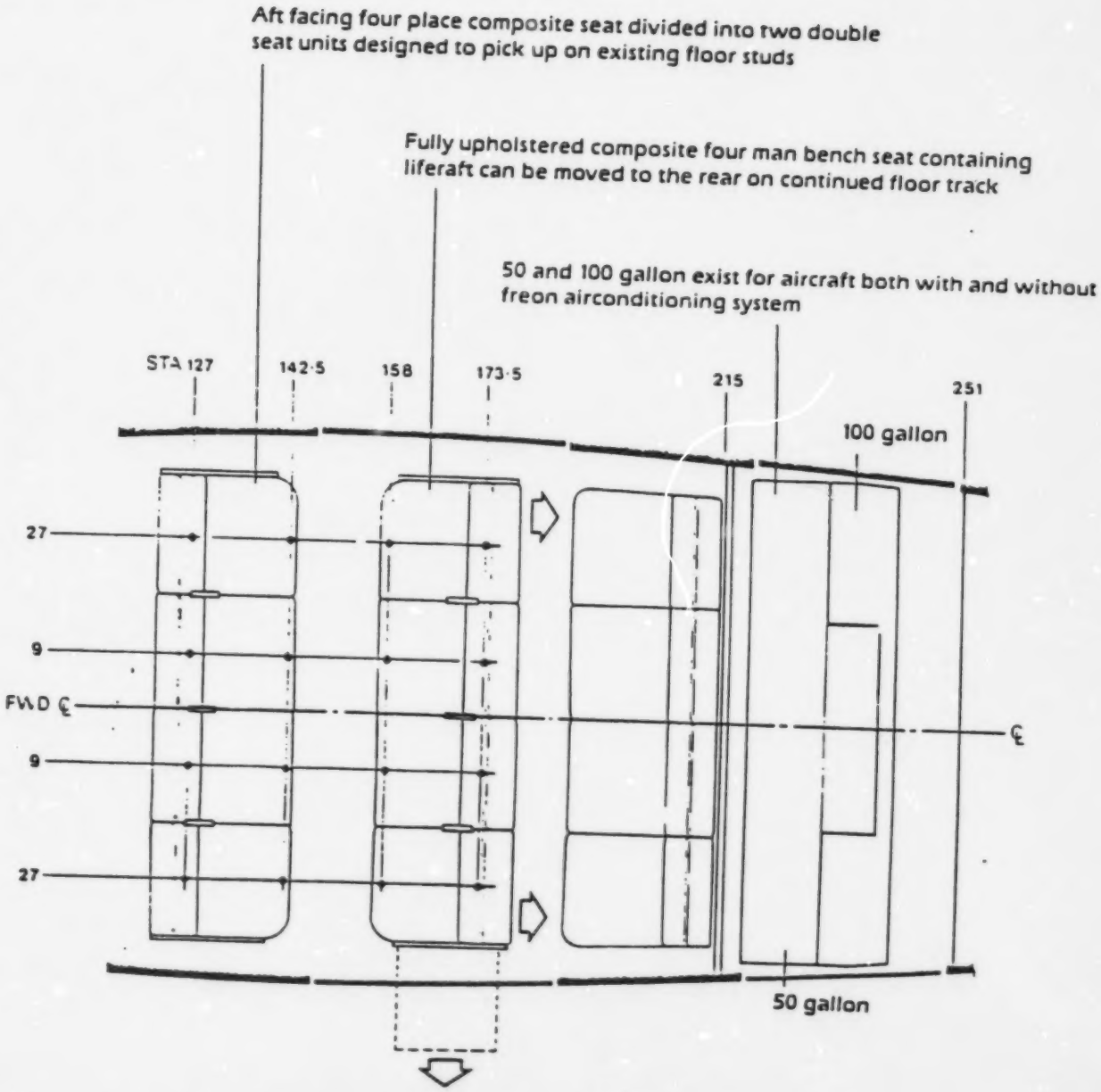
The general procedures outlined under Ditching (Flotation System) should be followed. Passengers and crew should be briefed to plan to exit the aircraft as soon as the rotor blades have stopped turning.

10. If the helicopter is unstable or taking on water, shut down engines, notify cabin occupants to evacuate through the cabin doors after the rotor blades have stopped turning. Use of the rotor brake is not recommended, especially above 40% N_r.

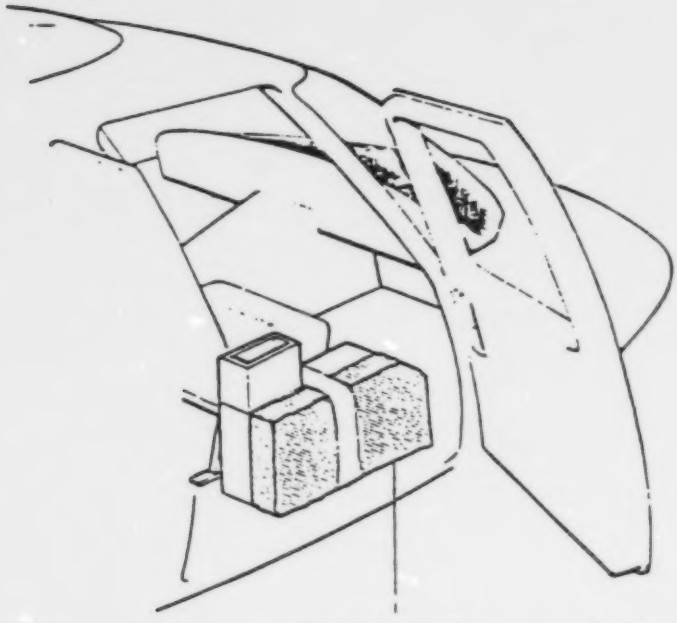
WARNING

Do not evacuate the helicopter until the rotor blades have stopped turning. Do not inflate life vests until clear of the helicopter.

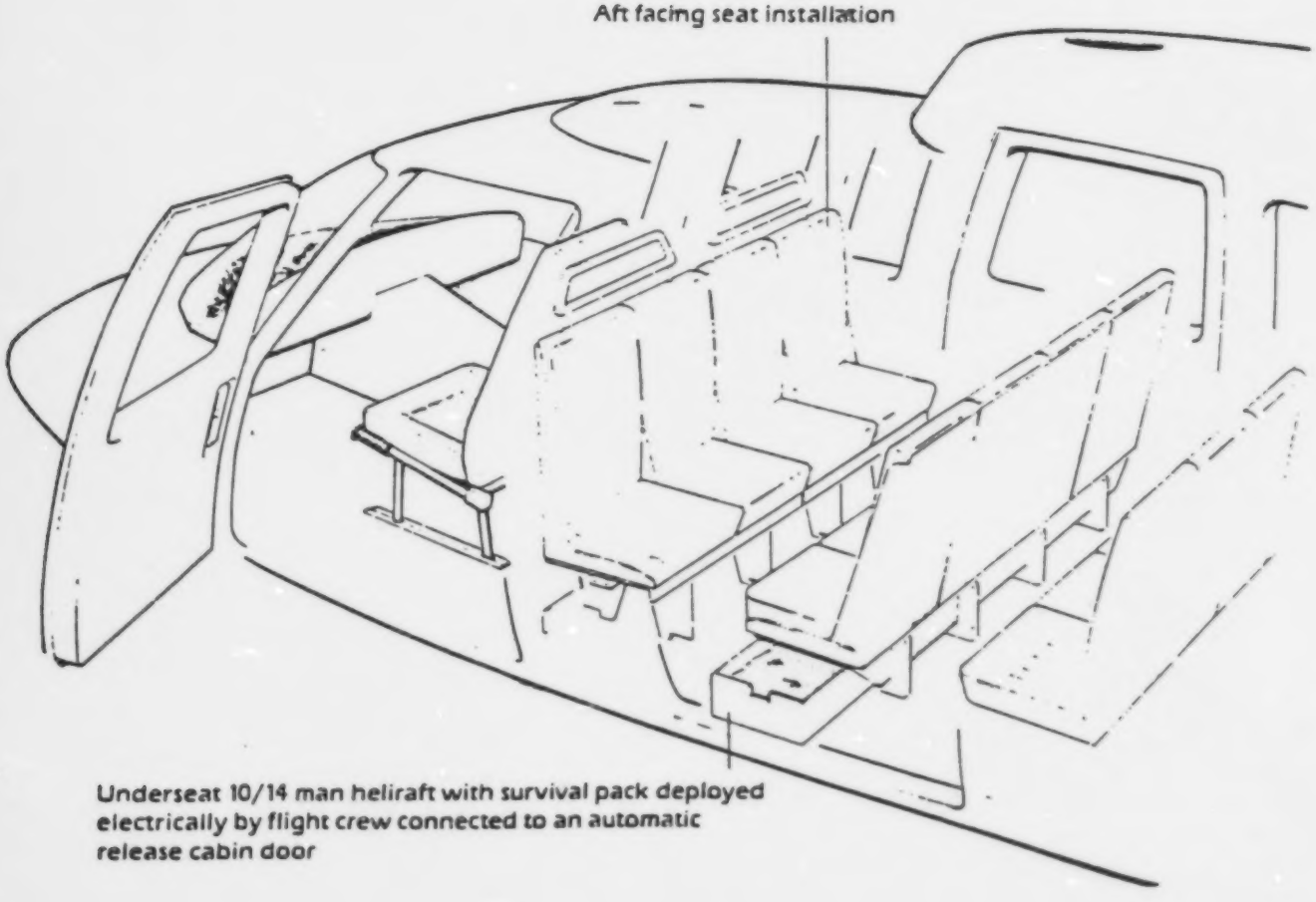
Metair Equipment for the Sikorsky S76 A and B Aircraft


Aft facing four place composite seat divided into two double seat units designed to pick up on existing floor studs
Fully upholstered composite four man bench seat containing liferaft can be moved to the rear on continued floor track
50 and 100 gallon exist for aircraft both with and without freon airconditioning system
STA 127
142·5
158
173·5
215
251
100 gallon
27
9
FWD ℄
9
27
℄
50 gallon

Auxiliary fuel tank systems comprising of 50 and 100 US gallon installations fitted in the baggage compartment



Forward 10/14 man heliraft with survival pack manually deployed by flight crew



Underseat 10/14 man heliraft with survival pack deployed electrically by flight crew connected to an automatic release cabin door

Liferaft stowage and deployment system

Metair product range

Cabin Interiors
Passenger and Aircrew seating, Flight Attendant Seats
Galleys, Wardrobes, Closets
Vanity Installations, Toilets
Electrical Flushing W.C.
Overhead Bins, Bulkheads, Baggage Containers
Cabin Crew Bunks
Bassinets
Floor Panels
Cabin Lighting and Emergency Lighting Systems
In-Flight Entertainment Systems and Wiring Harnesses
Air Conditioning Installations
Galley Hardware and Furnishings
Acoustic Installations
Avionic Installations
Auxiliary Long Range Fuel Systems
Specialised Military Systems and Applications
Rescue Hoist Installations
Composite Fabrications and Mouldings
Composite Tooling and Moulds
Sandwich Panel Fabrications
Sandwich Panel Inserts and Fittings
Thermoforming of Plastics
Precision Machining
Sheet Metal Fabrication
Design, Manufacture, Installations, Modifications and A/C Painting
Certification of Aircraft Equipment to Customer Requirements

The experience gained in more than a quarter of a century devoted to supplying the needs of the Aircraft Industry has led to the high reputation enjoyed by Metair Aircraft Equipment Ltd. We are located at the Air Station, West Malling, Kent, England, where we control all aircraft operations, thus giving our customers the unique service of a private airfield with a 6000 ft runway which is equipped to handle all their needs. At our facilities, we employ over 300 people in the design, manufacture and installation of passenger environment equipment. We are concerned with every aspect of improving the comfort and utilisation of the cabin, both for the Operator and his passengers.

We are a C.A.A. approved A1 Primary Company, reference number DA1/6683/62.

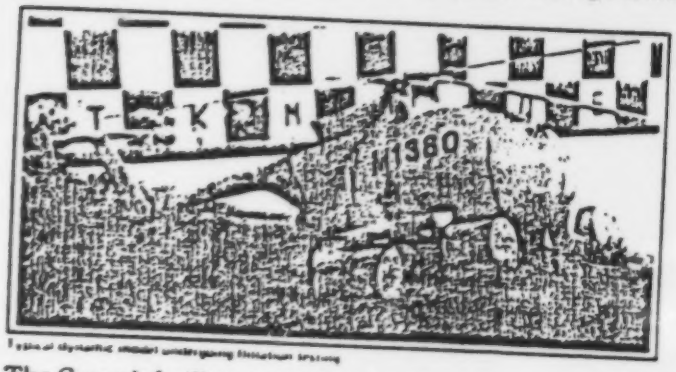
We also have the following approvals:—
Boeing under F.A.A. authority
Aerospatiale under D.G.A.C.
SAAB-SCANIA under the B.G.A.
British Aerospace under C.A.A.

Our Test House is equipped to conduct all necessary tests to verify the suitability of the materials used in our equipment. Including an O.S.U. test chamber, which is F.A.A. and C.A.A. approved.

Metair Aircraft Equipment Limited
The Air Station, West Malling, Kent ME19 6AP
☎ (0732) 848555
Fax: (0732) 844883
Telex: 957341 (Metair G)

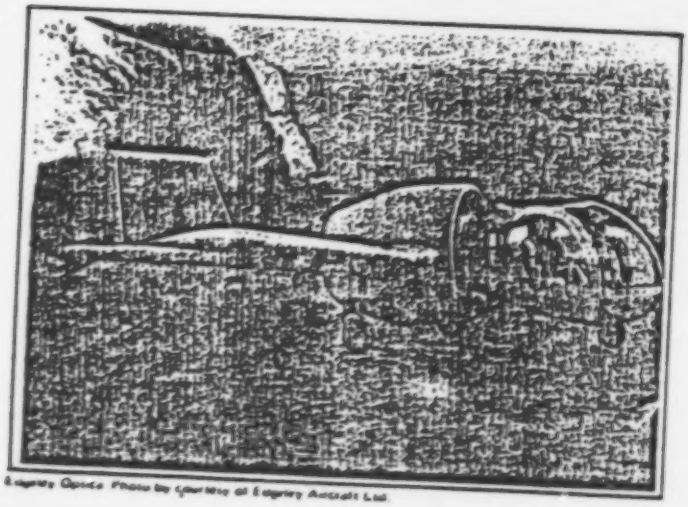
COMPLETE SERVICE

A unique integrated service is provided by EEL and FPT, in association with the Group's Hydrodynamic Testing Facilities.



Typical dynamic model undergoing flotation testing

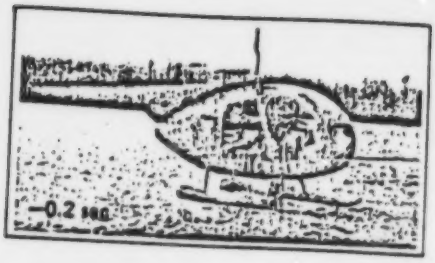
The Group's facilities include model testing, in which the behaviour of helicopters and fixed wing aircraft during ditching is investigated – these facilities are unique in the world. Tests in this establishment provide the basic data from which CAA and FAA regulations are formulated. Customers include Agusta, Bell, Boeing Vertol, Sikorsky, Hughes, MBB and Westland – as well as defence forces world-wide.

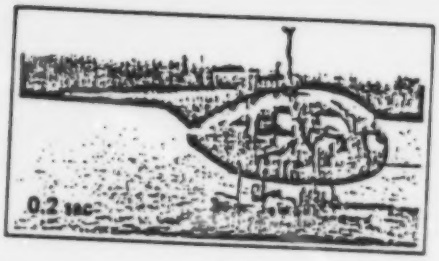


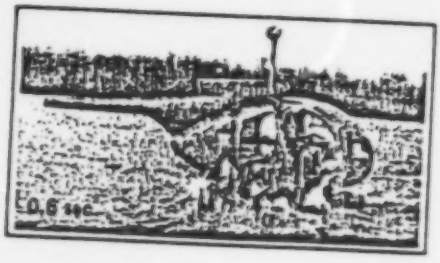
Eagle Quick Fleet by courtesy of Eagle Aircraft Ltd

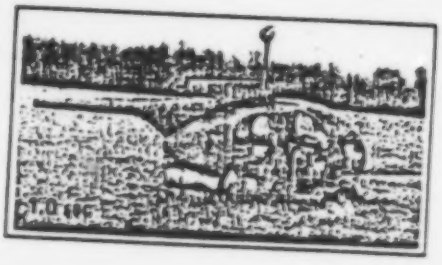
EEL Limited is a company specialising in pneumatic and electronic control systems, and provides design and project management, together with the supply of pneumatic and electrical systems.

FPT Industries' Hycafloat flotation products equip a range of helicopters including Lynx, Sea King, Wasp, Wessex, Westland 30 and is under development for the Boeing H–46. Rigid and flexible buoyancy aids for fighting vehicles also form part of FPT Industries extensive range of products in the survivability field.









Hughes 369D full scale ditching test

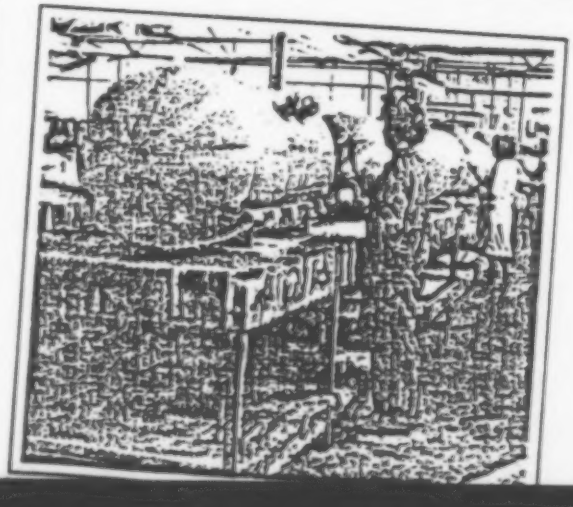
EEL Limited
A Westland Company
Kemp Building, Castle Street,
East Cowes, Isle of Wight, England PO32 6RA

FPT

Lightweight Emergency Flotation Equipment

A new generation of Emergency Helicopter Flotation Equipment for new or retrofit applications is now available from world leaders EEL and FPT. The two companies – both part of the Westland Technologies Group – have combined their resources to develop a Lightweight Emergency Flotation System which provides a significant milestone in aircraft safety for overwater operators of both helicopters and light aircraft. The companies' experience in this field spans 25 years, encompassing design and model testing, development testing, approval and manufacturing of flotation systems for helicopters, aircraft and marine vessels.

- ☐ Light – generally 50% lighter than existing systems, extending operating range and payload.
- ☐ Rapid inflation – 2-3 seconds for enhanced stability.
- ☐ Quick installation – typically 30 minutes.
- ☐ Float re-packing times after periodic inspections reduced by up to 80%.
- ☐ Tough – float material is 200% stronger than nylon.
- ☐ Maintenance – minimal.
- ☐ Aerodynamics – low drag packages.
- ☐ Float Covers – Quick release, strong and designed to avoid grit ingress.
- ☐ Certification – Civil and Military.



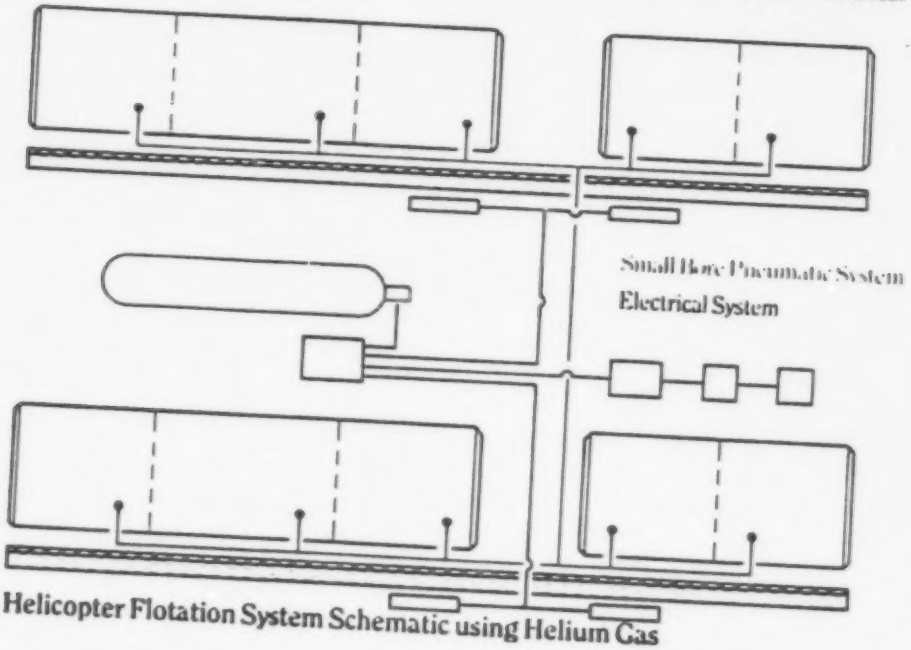
SYSTEM DESCRIPTION

Advanced materials technology and use of Helium as the inflation medium, – in preference to dry air, nitrogen or carbon dioxide, – account for the exceptionally high performance of the lightweight system.

Flotation bags are made from a special Urethane coated Kevlar material developed by FPT Industries. The material is far stronger than the traditional woven nylon or polyester fabric and has superior creep resistance, is intrinsically flame-resistant, and has high resistance to puncturing. The Urethane coating has been specially formulated by FPT Industries to contain the highly permeable helium gas.

Composite platforms, tailored to the particular aircraft type, carry the lightweight flotation bags and can quickly be secured to the aircraft structure. Automatic inflation of the emergency floats is recommended with initiation by submersion switches on ditching. With this system, a manual override is also provided. On initiation, gas is discharged into the floats from a high strength filament-wound pressure vessel(s) via pyrotechnic or solenoid operated valve(s). To avoid inadvertent inflation, the electrical system is manually armed after take off from the cockpit panel.

An emergency flotation system developed under contract to the U.S. Army for use on Hughes 500 helicopters weighs less than 90 lbs., takes less than 30 minutes to fit and demonstrates a two-second inflation time. The helicopter will survive in sea state 5 for over 30 minutes.



Helicopter Flotation System Schematic using Helium Gas

SYSTEM SPECIFICATION

TYPICAL INSTALLATION

Inflation Medium:	Gaseous Helium
Float Operating Pressure:	2 p.s.i.g.
Bottle Operating Pressure:	3000 p.s.i.g.
Supply voltage:	20v D.c.
Power Consumption (Armed):	50m.A.
Power Consumption (Fire):	5 A.
Max. no fire current:	1 A.
Inflation Time:	2 secs.
Operating Temp. Range:	–10°C to 55°C
Soak Temp. Range:	–40°C to 55°C
Limiting Sea State:	6

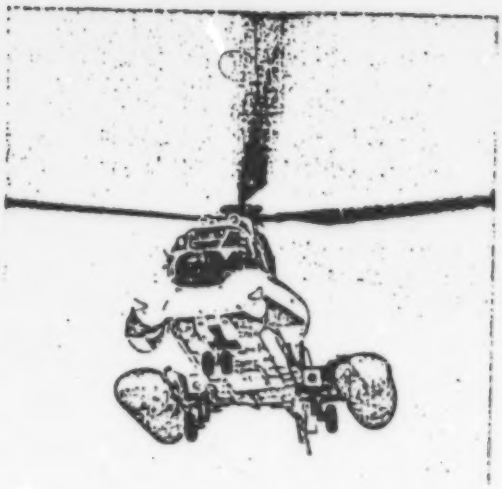
The following represents an installation for an 8000 lbs helicopter

Component	Volume (total)	Weight (lbs)	%weight saving*
Floats and Covers	162 ft^3	60	40
Bottles and Valves	1800 ins^3	32	55
Pneumatic System		10	35
Platform Assemblies		24	60
Electrical System		8	–
Ancillaries & Fastenings		16	30
Total		150	46
% Aircraft Weight	: 1.875	(*3.39) saving 127.4lbs	
% Payload	: 4.08	(*7.54) saving 127.4lbs	

*over current generation equipment

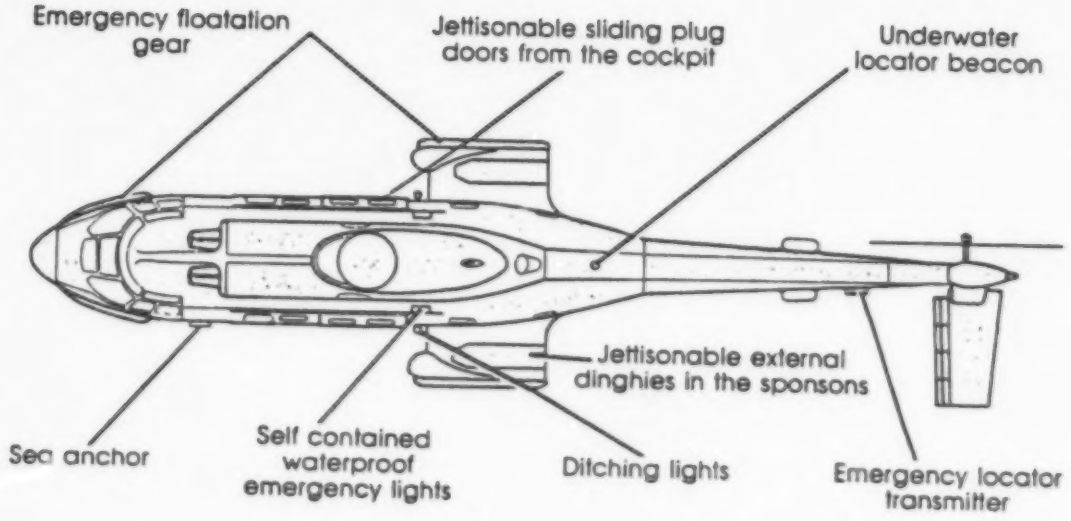
SUPER PUMA

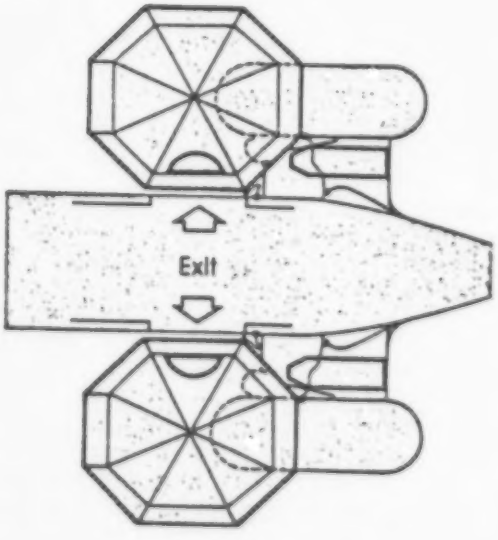
AS 332 L

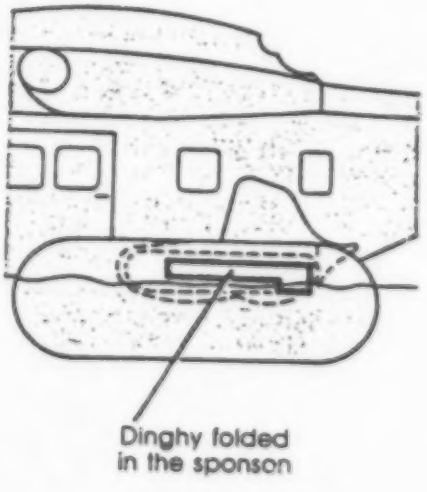


emergency floatation gear

- emergency floatation gear stable up to state 7
- life-rafts with survival kit, integrated in the landing gear fairings, jettisonable from the cabin and the cockpit



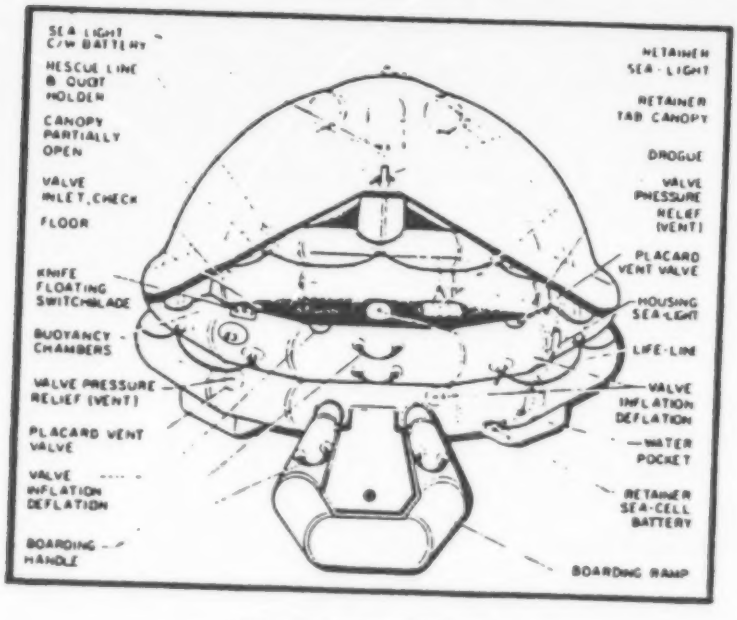




AIRLINE LIFERAFT

TYPE 4XL MK1-B/R, P/N TUL-6162

APPROVAL: MOT - CANADIAN ARMED FORCES



DESIGN DATA

O.D. MAIN TUBE (ACROSS FLATS)		1905 mm	75.00 ins.
I. D. MAIN TUBE (ACROSS FLATS)		1448 mm	57.00 ins.
LOWER TUBE DIA		229 mm	9.00 ins.
UPPER TUBE DIA		216 mm	8.50 ins.
VOLUME UPPER TUBE	0.197 m^3 / 6.96 cu.ft	197 kg	435 lbs Buoyancy
VOLUME LOWER TUBE	0.221 m^3 / 7.81 cu.ft	221 kg	487 lbs Buoyancy
VOLUME ARCH TUBES	0.066 m^3 / 2.34 cu.ft	66 kg	146 lbs Buoyancy
VOLUME BOARDING RAMP	0.065 m^3 / 2.28 cu.ft	64 kg	142 lbs Buoyancy
BUOYANCY MAIN TUBES ONLY		418 kg	921 Lbs.
EFFECTIVE DISPLACEMENT		1179 kg	2600 lbs.
FREEBOARD (UNLADEN)		445 mm	17.50 ins.
O/A HEIGHT (EXCLUDING WATER POCKETS)		1194 mm	47.00 ins.
PACKED SIZE IN STD. VALISE	660mm x 406mm x 254mm		26 ins x 16 ins x 10 ins.

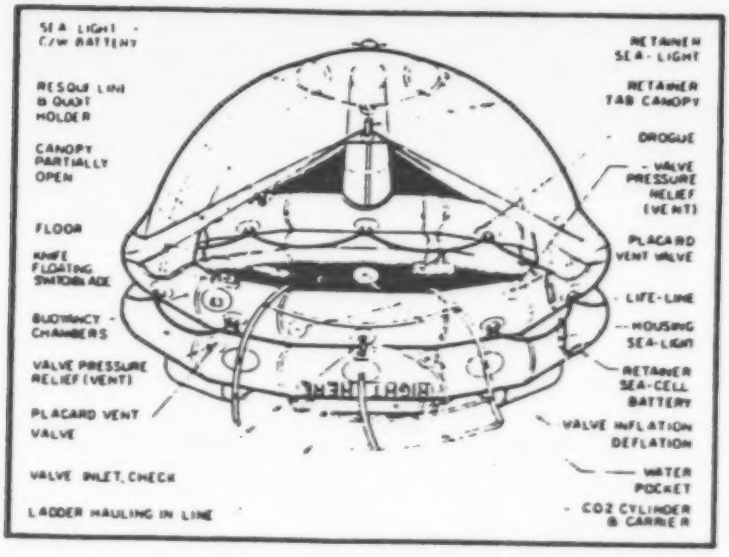
WEIGHT DATA

LIFERAFT, LESS INFLATION SYSTEM, ANCILLARY EQUIP. & EMERGENCY RATIONS	11.23 kg	24 lbs 12 oz.
ANCILLARY EQUIPMENT & BELLOWS BAG	1.59 kg	3 lbs 8 oz.
EMERGENCY RATIONS	6.46 kg	14 lbs 4 oz.
CO2 CYLINDER & HOSE	5.84 kg	12 lbs 14 oz.
VALISE CONTAINER	1.13 kg	2 lbs 8 oz.
LIFERAFT, COMPLETE, PACKED IN VALISE CONTAINER .... APPROX	26.31 kg	58 lbs.

AIRLINE LIFERAFT

TYPE 4XL , P/N TUL-6140

APPROVAL - MOT - Canadian Armed Forces -



DESIGN DATA

O.D MAIN TUBE (ACROSS FLATS)			1930 mm	76.00 ins.
I.D. MAIN TUBE (ACROSS FLATS)			1422 mm	56.00 ins.
LOWER TUBE DIA			254 mm	10.00 ins.
UPPER TUBE DIA			216 mm	8.50 ins.
VOLUME UPPER TUBE	0.197 m^3	6.96 cu.ft	201.85 kg	445 lbs Buoyancy
VOLUME LOWER TUBE	0.273 m^3	9.64 cu.ft	279.87 kg	617 lbs Buoyancy
VOLUME ARCH TUBES	0.066 m^3	2.34 cu.ft	67.59 kg	149 lbs Buoyancy
BUOYANCY MAIN TUBES ONLY			467.21 kg	1030 lbs.
EFFECTIVE DISPLACEMENT			1179.36 kg	2600 lbs.
FREEBOARD (UNLADEN)			470 mm	18.50 ins.
O/A HEIGHT (EXCLUDING WATER POCKETS)			1219 mm	48.00 ins.
PACKED SIZE IN STD. VALISE			610 mm x 406mm x 178 mm	24 ins x 16 ins x 7 ins.

WEIGHT DATA

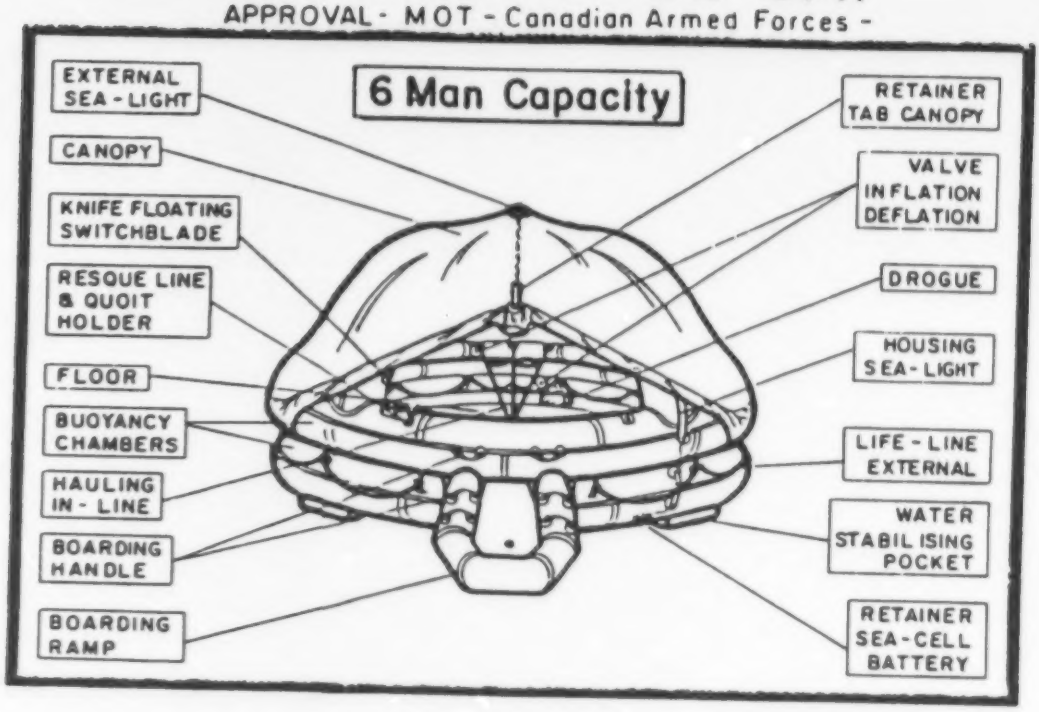
LIFERAFT, LESS INFLATION SYSTEM AND ANCILLARY EQUIPMENT	10 kg	22 lbs 1 oz.
CO_2 CYLINDER C/W HOSE AND "Y" CONNECTOR	5 kg	11 lbs 2 oz.
ANCILLARY EQUIPMENT	3 kg	6 lbs 12 oz.
VALISE CONTAINER, C/W OPERATING CORD	1 kg	2 lbs 4 oz.
TOTAL WEIGHT, PACKED IN VALISE CONTAINER	APPROX 19.28 kg	42½ lbs

AIRLINE LIFERAFT

(NSN 4220-21-812-5478)

TYPE 6XL(C), P/N TUL-6141

APPROVAL - MOT - Canadian Armed Forces -



DESIGN DATA

O.D. MAIN TUBE			2 223 mm	87.50 ins.
I.D. MAIN TUBE			1 676 mm	66.00 ins.
LOWER TUBE DIA			273 mm	10.75 ins.
UPPER TUBE DIA			216 mm	8.50 ins.
VOLUME UPPER TUBE	0.224 m^3	7.90 cu.ft.	238.59 kg	526 lbs. Buoyancy
VOLUME LOWER TUBE	0.355 m^3	12.55 cu.ft.	364.24 kg	803 lbs. Buoyancy
VOLUME ARCH TUBES	0.132 m^3	4.65 cu.ft.	135.17 kg	298 lbs. Buoyancy
VOLUME BOARDING RAMP	0.083 m^3	2.94 cu.ft.	85.28 kg	188 lbs. Buoyancy
BUOYANCY MAIN TUBES ONLY			602.83 kg	1 329 lbs.
EFFECTIVE DISPLACEMENT			2 018.07 kg	4 449 lbs.
FREEBOARD (UNLADEN)			489 mm	19.25 ins.
O/A HEIGHT (EXCLUDING WATER POCKETS)			1168 mm	46.00 ins.
PACKED SIZE IN R/S VALISE	762mm x 470mm x 254 mm			30ins x 18.50ins x 10 ins.

WEIGHT DATA

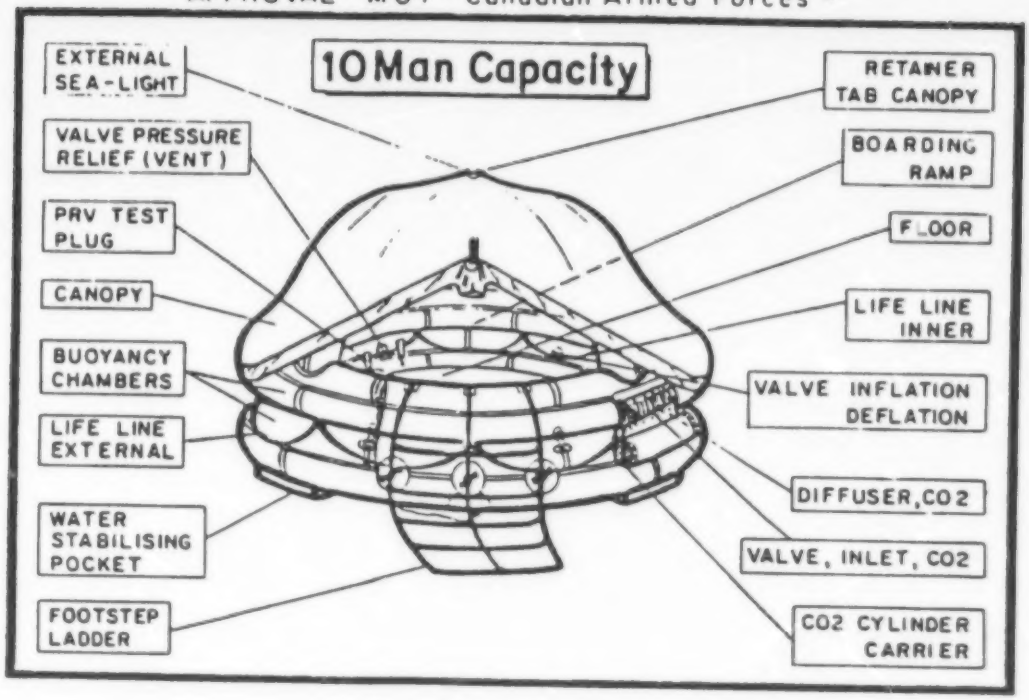
LIFERAFT, LESS INFLATION SYSTEM	12.47 kg	27.50 lbs.
CO_2 CYLINDER	7.48 kg	16.50 lbs.
VALISE CONTAINER, TYPE R/S	2.04 kg	4.50 lbs.
TOTAL WEIGHT, LESS ANCILLARY EQUIPMENT	22.23 kg	49.00 lbs.

AIRLINE LIFERAFT

(NSN 4220-21-869-4417)

TYPE 10 XL C MKII, P/N TUL-6143

APPROVAL - MOT - Canadian Armed Forces -



DESIGN DATA

O.D. MAIN TUBE			2 623 mm	103.25 ins.
I.D. MAIN TUBE			1 988 mm	78.25 ins.
LOWER TUBE DIA			318 mm	12.50 ins.
UPPER TUBE DIA			254 mm	10.00 ins.
VOLUME UPPER TUBE	0.414 m^3	14.63 cu.ft	424.12 kg	935 lbs. Buoyancy
VOLUME LOWER TUBE	0.594 m^3	20.96 cu.ft	607.82 kg	1340 lbs. Buoyancy
VOLUME ARCH TUBES	0.158 m^3	5.58 cu.ft	161.94 kg	357 lbs. Buoyancy
VOLUME BOARDING RAMP	0.083 m^3	2.94 cu.ft	85.28 kg	188 lbs. Buoyancy
BUOYANCY MAIN TUBES ONLY			1031.94 kg	2 275 lbs.
EFFECTIVE DISPLACEMENT			3344.85 kg	7 374 lbs.
FREEBOARD (UNLADEN)			572 mm	22.50 ins.
O/A HEIGHT (EXCLUDING WATER POCKETS)			1219 mm	48.00 ins.
PACKED SIZE IN R/S VALISE		762 mm x 356 mm x 305 mm		30 ins x 14 ins x 12 ins.

WEIGHT DATA

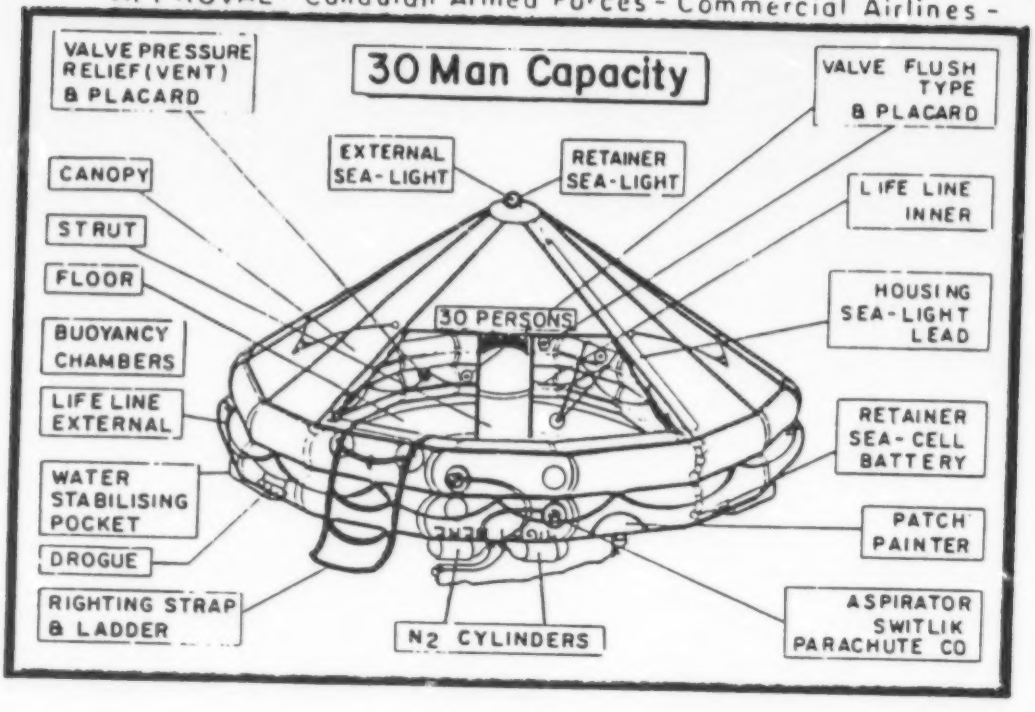
LIFERAFT, LESS INFLATION SYSTEM	16.33 kg	36 lbs.
CO_2 CYLINDER	10.43 kg	23 lbs.
VALISE CONTAINER, TYPE R/S	2.27 kg	5 lbs.
TOTAL WEIGHT, LESS ANCILLARY EQUIPMENT	29.48 kg	65 lbs.

AIRLINE LIFERAFT

(NSN 4220-21-871-6059)

TYPE 30XL, P/N TUL-6144 AC-SA

APPROVAL - Canadian Armed Forces - Commercial Airlines -



DESIGN DATA

O.D BUOYANCY TUBES (ACROSS FLATS)		4 045 mm	159.25 ins.
I. D. BUOYANCY TUBES (ACROSS FLATS)		3 334 mm	131.25 ins.
TUBE DIA		356 mm	14.00 ins.
VOLUME BUOYANCY TUBE 1.246m^3	44.00 cu.ft.	1 277.34 kg	2816 lbs. Buoyancy
VOLUME BOARDING RAMP .0083m^3	2.94 cu.ft.	85.28 kg	188 lbs. Buoyancy
VOLUME CENTER STRUT 0.217m^3	7.67 cu.ft.	222.26 kg	490 lbs. Buoyancy
BUOYANCY, MAIN TUBES ONLY		2 554.68 kg	5 632 lbs.
EFFECTIVE DISPLACEMENT		8 337.17 kg	18 380 lbs.
FREEBOARD (UNLADEN)		711 mm	28 ins.
O/A HEIGHT (EXCLUDING WATER POCKETS)		1 829 mm	72 ins.
PACKED SIZE R/S VALISE	940mm x 787mm x 191mm		37ins x 31 ins x 7½ ins.

WEIGHT DATA

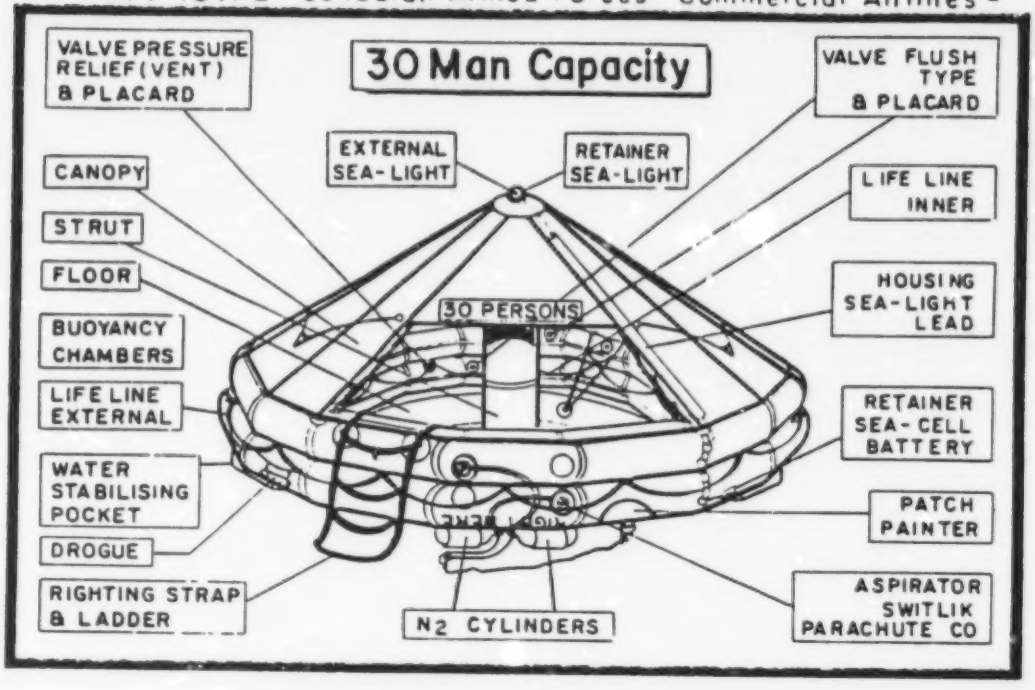
LIFERAFT, LESS INFLATION SYSTEM & ANCILLARY EQUIPMENT	24.95 kg	55 lbs.
N2 CYLINDERS, C/W HOSES AND FITTINGS	10.89 kg	24 lbs.
BELLOWS BAG	1.81 kg	4 lbs.
VALISE C/W RIP-STRIP & OPERATING CORD	2.27 kg	5 lbs.
RAFT COMPLETE, PACKED IN VALISE CONTAINER (LESS ANCILLARY EQUIPMENT) APPROX	39.92 kg	88 lbs.

AIRLINE LIFERAFT

(NSN 4220-21-871-6059)

TYPE 30XL, P/N TUL-6144 AC-SA

APPROVAL - Canadian Armed Forces - Commercial Airlines -



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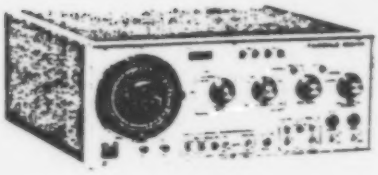
LVIS ENG 4-5-2

ARMY AVIATION

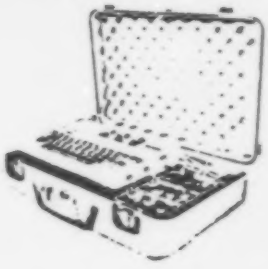
AIRCRAFT

GROUND SUPPORT AND TEST EQUIPMENT



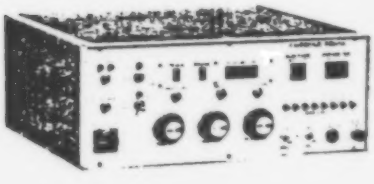
AIRCRAFT SIMULATOR

Simulates accurate aircraft data for input to DFR during bench test and calibration



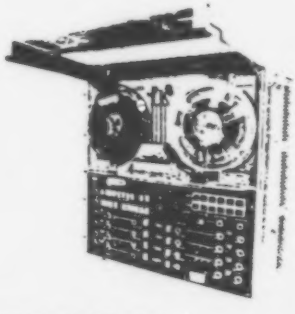
PORTABLE DATA DISPLAY UNIT

Displays and or prints selected data parameters on board in engineering values for periodic verification and automatic testing of data.



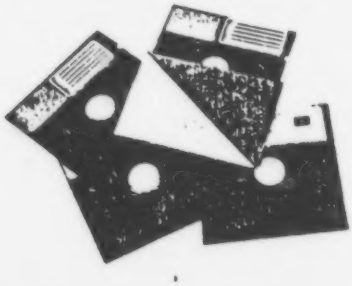
READ DATA UNIT

Regenerates data signal from DFR to read out computer for total analysis during bench check.



COPY RECORDER

High QualityRecorder for copying all DFR Tracks simultaneously for later analysis and playback. IEEE 488 Bus Controllable.



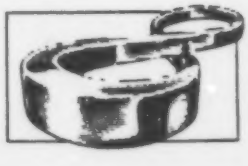
SOFTWARE SUPPORT DISKS

Computer programs avaliable for calibration and test for use with Apple II computer or IBM PC.

Mini-Computers are used to readout flight data and for bench test calibration.

FOR FURTHER INFORMATION PLEASE CONTACT:

FAIRCHILD AVIATION RECORDERS
PO BOX 3041
SARASOTA, FL 34230-3041
(813) 371-0811
TELEX: 4947160
TWX: 810-864-0406
FAX: 813-378-1893



FAIRCHILD WESTON SYSTEMS INC.

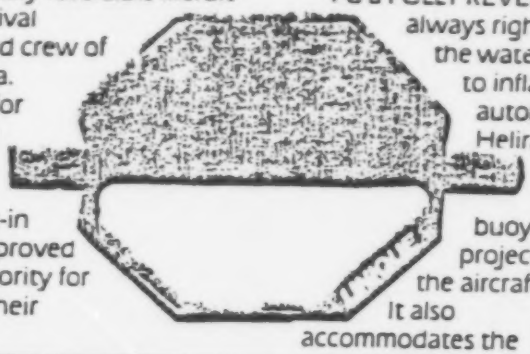
DATA SYSTEMS DIVISION
P.O. Box 3041, Sarasota, Florida 34230-3041
(813) 371-0811 - Telex: 4947160
Fax: (813) 378-1893

HELI

The first liferaft designed

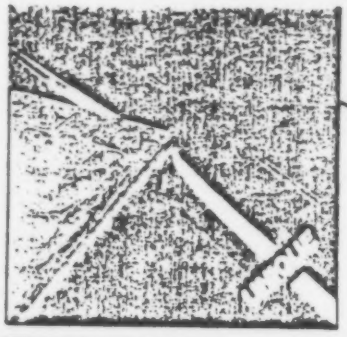
The new RFD Heliraft is a fully reversible liferaft designed as the primary survival equipment for passengers and crew of an aircraft forced down at sea.

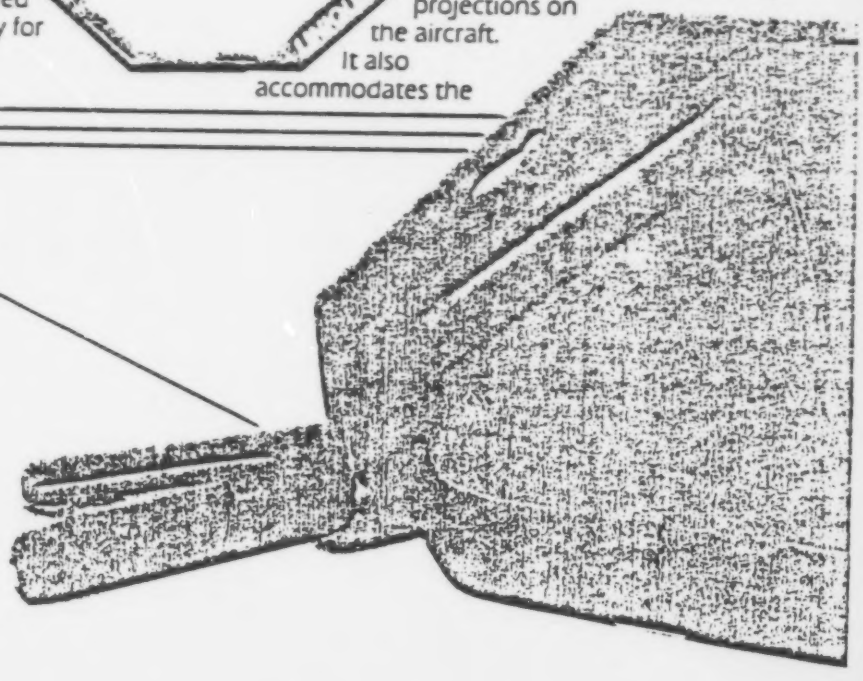
Designed from the outset for rotorcraft use, Heliraft – with unique features such as high damage resistance, a fast-deploying canopy and a built-in strobe beacon – has been approved by the UK Civil Aviation Authority for use on helicopters meeting their new specification.



As a FULLY REVERSIBLE design, Heliraft is always right-side-up when it goes into the water, and takes approx. 20 seconds to inflate through an integral semi-automatic inflation system.

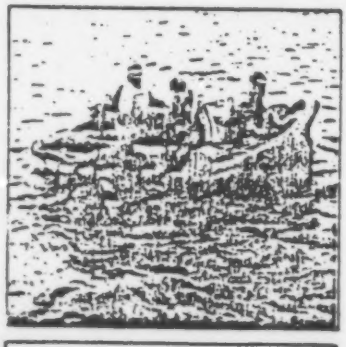
Heliraft's unique fender tube provides additional protection to the primary buoyancy chambers from sharp projections on the aircraft. It also accommodates the





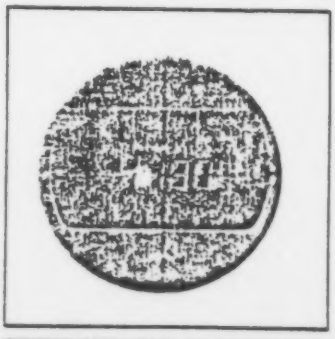
PROTECTION

The polyurethane-proofing of the fender cover gives Heliraft a **high level of resistance to damage.** In the unlikely event of puncture, the unique fender tube protection as well as the **four** separate compartments provide Heliraft with a **high degree of damage tolerance.**



BOARDING

Heliraft is extremely **easy to board.** Fully reversible large boarding ramps are incorporated at both entrances, making it easy to embark from the water.

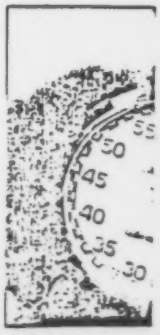


WEIGHT

Heliraft is **lightweight** and achieves significant fuel savings. In fact, despite its additional unique features, it weighs no more than liferafts currently in service. A fully approved emergency pack is also carried – (see back page)

STABILITY

Even in high seas or in the downdraught from a rescue helicopter, Heliraft demonstrates an unusually **high degree of stability.**



SPEED

Heliraft takes ... at 20 ... Initially, and to aid ... canopy stays open ... semi-automatically ... survivors are aboard ...

RAFT

specifically for helicopters

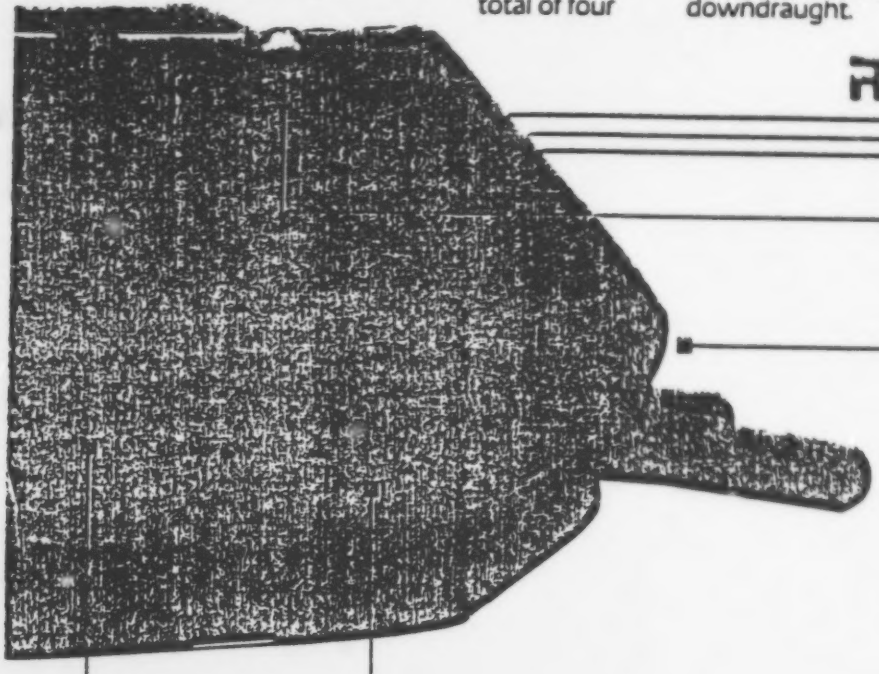
canopy and can be rotated through approximately 90 degrees – in either direction – to provide a highly flexible number of canopy positions.

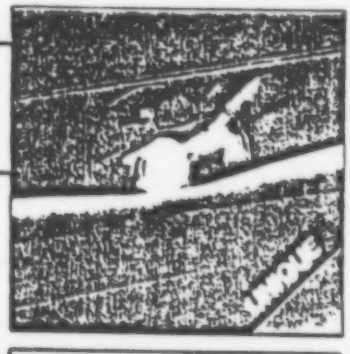
The Heliraft range includes 10, 14 and 18 person capacities and has an approved overload rating for rotorcraft.

The liferaft's fender/arch tubes have two separate compartments which are also separate from the two buoyancy chambers. This provides a total of four separate compartments and a considerable degree of DAMAGE TOLERANCE. The sections of the raft susceptible to damage from wreckage are polyurethane-proofed, with abrasion resistance at least 10 TIMES GREATER than existing neoprene coatings.

Once at sea, Heliraft demonstrates remarkable sea-keeping qualities and stability even when it is empty, or subject to helicopter downdraught.

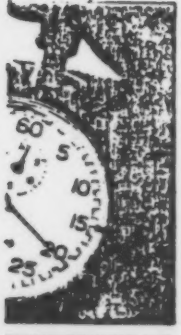
RFD AVIATION





DETECTION

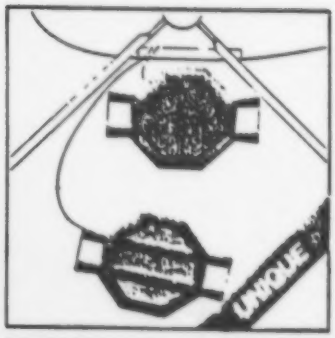
On inflation of the liferaft the **high-performance flashing beacon** is visible through a transparent panel in the fender tube. When the canopy is deployed the beacon is automatically repositioned at the apex of the canopy.



seconds to inflate. rating, the Heliraft's owever, it can be raised hen **60 seconds** once

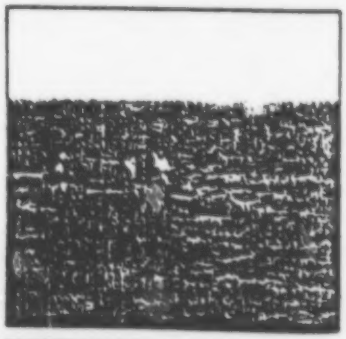
RESCUE

Unlike any other helicopter liferaft, Heliraft's **canopy can be lowered quickly and completely** to assist in air sea rescue situations (see back cover).



EMBARKATION

The Heliraft's short mooring line (5'6", 1.6m) maintains the raft in the helicopter doorway for **fast dry embarkation** from the aircraft. The long mooring line (35', 10.6m) for back-up enabling the raft to stand off the helicopter.



VISIBILITY

During boarding, Heliraft's canopy is stowed and does not impair **visibility** of survivors in the raft or those in the water.

HELIRAFT

SPECIFICATION

10 Person Capacity	
Outside dimensions (including fender)	2.98m
Outside dimensions (excluding fender)	2.55m
Inside dimensions	2.04m
Maximum across boarding ramps	4.57m
Height (canopy stowed)	0.51m
Height (canopy raised)	1.3m
Typical valise dimensions	720 x 380mm dia.
Typical packed weight (approx.)	34 Kg.

14 Person Capacity	
Outside dimensions (including fender)	3.39m
Outside dimensions (excluding fender)	2.97m
Inside dimensions	2.4m
Maximum across boarding ramps	5.0m
Height (canopy stowed)	0.56m
Height (canopy raised)	1.43m
Typical valise dimensions	815 x 375mm dia.
Typical packed weight (approx.)	39 Kg.

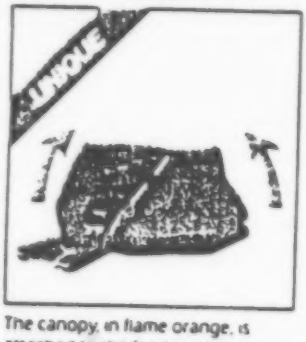
18 Person Capacity	
Outside dimensions (including fender)	3.66m
Outside dimensions (excluding fender)	3.23m
Inside dimensions	2.63/2.89m
Maximum across boarding ramps	5.55m
Height (canopy stowed)	0.6m
Height (canopy raised)	1.6m
Typical valise dimensions	925 x 395mm dia.
Typical packed weight (approx.)	48 Kg.

Emergency Survival Pack (North Sea Scale)

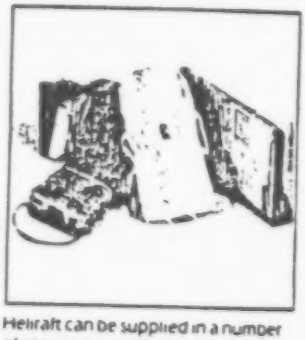
1 Survival Aids Bag, 1 Contents Card, 1 First Aid Kit, 1 Torch, 1 Miniture Pack, 4 Day Signals/Night, 3 Leak Stoppers,1 Pump, 2 Sponges, 1 Baler, 2 Survival Bags, 1 Water Sachet 500 ml, 1 Immediate Action Card, 1 Survival Flipcard, 1 Heliograph, 2 Light Sticks, 2 Hand Warmers, 1 Body Warmer, 1 Anti-seasickness tablets (60 off), 1 Drinking Cup, 1 Rescue Line, 2 Paddles.

Boarding Heliraft is made easier because the canopy remains down. It can also be lowered – or partly stowed – to help survivors leave the raft during rescue.

Thanks to its patented design, the canopy does not have to be simply open or closed - it can be deployed at various stages in between.



The canopy, in flame orange, is attached to the fender/archtube. The doors may be left open or closed.



Heliraft can be supplied in a number of **stowage options** for S61, S76, B212, B214ST, SA330, SA332, SA365, MBB105, BV234, WG30 and more . . .

Authorised Agent

RFD AVIATION

RFD Aviation, Catteshall Lane, Godalming, Surrey GU7 1LH England
Telephone: Godalming (UK STD code 04868) 4122. Telex: 859233.

Setting the standard in safety and survival

METAIR LIFEHATCH fitted to Sikorsky S61 Helicopters
Part No. 01-42

General

The METAIR lifehatch completely replaces the rear emergency hatch and is fitted with a completely independant door bolting system. The lifehatch and standard hatch are completely interchangeable for mixed overwater/overland operation.

The lifehatch comprises a hatch panel, cover panel and strikeplate installation. The cover panel is available in two sizes to accommodate different sized liferafts.

The lifehatch, part number 01-42-3, will accept any inflatable liferaft pack up to 38 ins. long by 15 ins. diameter with a maximum weight limit of 132.2 lbf.

The lifehatch, part number 01-42-4, will accept any inflatable liferaft pack up to 40 ins.long by 18 ins.diameter with a maximum weight limit of 132.2 lbf.

This includes:-

Pan Avion	C-25-2
	C-10-2
R.F.D.	30U MklVd
	26U Mklc
	18U Mkl
	10U Mk8

The hatch panel, which is manufactured from glass reinforced plastic (GRP) is the major structural component. Attached to this are the door bolting mechanism and liferaft retention strap. The four door securing bolts are actuated by a linkage of pushrods and levers acted on by either of two handles, one internal, the other external, or an electrical actuator operated from the cockpit

The liferaft is secured to the hatch panel by the single 2" retention strap. A quick release buckle on the strap enables the liferaft to be released and carried to an alternative exit for launching. In normal operation the mechanism in the lifehatch releases the strap which then releases the life raft during inflation.

The liferaft when attached to the hatch panel is protected from damage by a cover assembly. The cover is removed by pulling on two handles for access to the liferaft or latch mechanism.

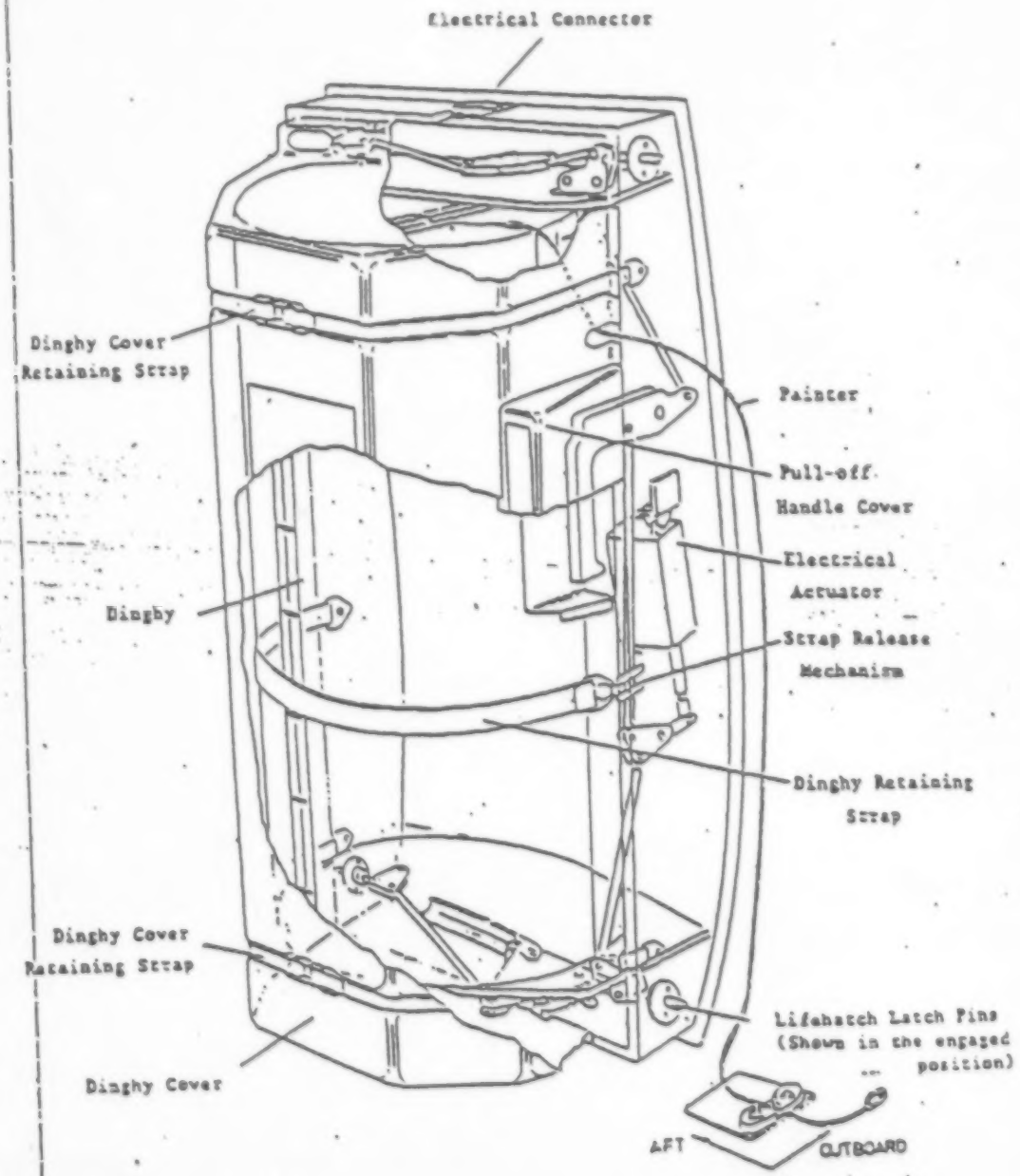
Operation

The liferaft can be operated by remote control from the cockpit or manually at the hatch. There is a manual release handle both inside and outside the helicopter.

In the cockpit the control is a guarded switch. Lifting the guard and operating the switch causes the actuator to release the hatch and launch the raft. The internal and external handle mechanically release the hatch.

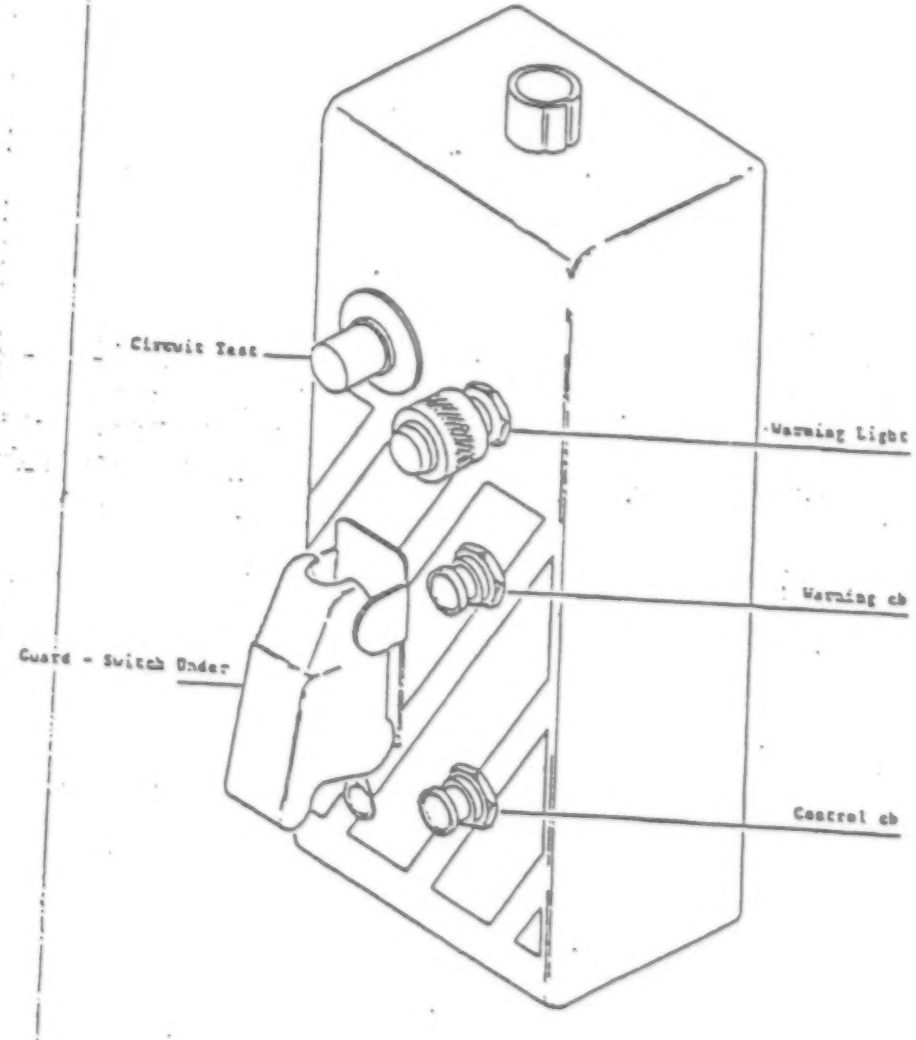
As the released lifehatch falls out the lanyard tightens and operates the gas cylinder automatically inflating the raft.

In the event of the helicopter attitude preventing the lanyard inflating the liferaft a sharp tug on the lanyard will cause inflation to commence.



LIFEHATCH

Fig. 1



COCKPIT CONTROL PANEL

Fig. 2

A - 4

WIRE WARNING DEVICES